GENOTYPIC DIFFERENCES IN PEARL MILLET (PENNISETUM GLAUCUM L.) IN RELATION TO SALT- TOLERANCE

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CERTIFICATE

I have pleasure in forwarding this thesis of Ms. Bhatti Pranali Madanbhai, entitled, **"GENOTYPIC DIFFERENCES IN PEARL MILLET (PENNISETUM GLAUCUM L.) IN RELATION TO SALT-TOLERANCE"** for acceptance for the degree of Ph. D. in Botany. The results embodied in this thesis are original and have not been submitted for the award of any degree of any University.

Ms. Bhatti Pranali Madanbhai has put in more than six terms of research work in this department under my supervision.

(Prof. A. N. Pandey)

Guide Teacher

Forwarded through

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Department of Biosciences,

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DEDICATED

TO

MY BELOVED PARENTS

AND

MY BROTHER

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1.

INTRODUCTION

INTRODUCTION

Salinity, sometimes referred to as a 'quiet crisis' (Haw *et al*., 2000), is a major environmental problem affecting crop production around the world. According to different estimates, up to 7% of the total land surface on earth is saline (Flowers and Yeo 1995; Elphick *et al*., 2001). According to Daniel *et al.* (2004), the area of saline soils on the globe is 6.2 m ha in North America, 2.0 m ha in central America, 69.4 m ha in south America, 53.5 m ha in Africa, 83.3 m ha in south Asia, 91.6 m ha in north and central Asia, 20.0 m ha in southeast Asia, 17.4 m ha in Australasia and 7.8 m ha in Europe. Eventually, salinity affects 351.5 m ha land of the globe. The problem of soil salinity is especially critical in semi arid and arid regions of the world (Munns, 2005). In dry regions amount of rainfall is insufficient for substantial leaching of salts and consequently, soils become saline over a prolonged period of time. In addition, with intensive irrigation, about one third of the world's irrigated land is suffering from secondary salinisation (Flowers and Yeo, 1995). The economic penalties due to loss of agricultural production are in the range of billions of dollars. Apart from agricultural crops, salinity is also a scourge for forestry, pasture development and other similar practices. Consequently, the total loss of production due to salinity can be estimated to a much greater extent.

Salt affected soils

Under arid and semiarid conditions, and in regions of poor natural drainage, there is a real hazard of salt accumulation in soils. The processes by which soluble salts accumulate in soils include irrigation with water containing salts, upward movement

of moderate-to saline water from high water tables, and weathering of primary and secondary minerals in the soils. Accumulation of soluble salts in the soil solution imposes stress on growing crops that can lead to decreased yields and, in severe cases, complete crop failure. Properties of saline and sodic soils are determined by the composition of the soil solution and that of the solid phase. The composition of the soil solution is determined by the total concentration of soluble salt, or 'salinity', concentration of sodium relative to other cations, or 'sodicity' with anionic composition of the water, especially that of bicarbonate and carbonate. Total salt concentration is determined by total dissolved solids (TDS) in milligrams per liter of salts, by the ionic concentration in millimoles of charge per liter and by the electrical conductivity (EC) in deciSiemens per meter. The relationship between salt concentration, either millimoles of charge per liter or milligrams per liter and EC of various salt solutions, respectively (Daniel *et al*., 2004). According to the definition of the US Salinity Laboratory the saturation extract (the solution extracted from a soil at its saturation water content) of a saline soil has an electrical conductivity (EC) greater than 4mmho cm^{-1} or 4 deciSiemens m^{-1} (equivalent to ~ 4mM NaCl l^{-1}) and an exchangeable sodium percentage (ESP) of less than 15.

Response of crops to salinity

Salinity affects plant growth by three mechanisms (Daniel *et al*., 2004):

1. Osmotic effects limit the ability of plants to absorb water from the soil solution. The osmotic effect is demonstrated when plant growth is reduced in a similar way by iso-osmotic solutions, and when osmotic and soil-water matric potential have a similar and additive effect on plant growth.

2. Specific ion toxicity results from excessive concentrations of Na or Cl ions, an effect most commonly found in woody species.

3. Changes in soil physical and chemical properties can affect plant production.

Crop yield is not reduced until a threshold salinity level is exceeded. Beyond the threshold level, the yield decreases linearly with rising salinity. The salinity values at zero yields provide an estimate of maximum salinity that plants can tolerate. Plants can be divided into four groups (sensitive to tolerant) according to their response to salinity. Of the field crops, barley, cotton, and sugar beet belong to the tolerant group, wheat and soybean belong to the moderately tolerant group, peanut and rice belong to the moderately sensitive group, and beans and cowpeas belong to the salt-sensitive group.

Plant response to salinity depends also on soil, climate, and plant factors. Soil-water content and frequency of irrigation affect the tolerance of crops to soil salinity. Shortening the irrigation intervals minimizes the deleterious effect of salinity. The salt tolerance of many crops is enhanced when daily drip irrigation is used. Climate can also modify plant response to salinity. Salt tolerance is often reduced under hot, dry conditions; also, crops appear to be more salt-tolerant in areas with air pollution that limits plant growth.

Plant factors such as stage of growth, variety, and rootstock affect plant response to salinity. Rice, barley, wheat, and corn are most sensitive to salinity during the early

seedling stage. Beet and sunflower are more sensitive to salinity during germination than in later stages of growth. Salinity effects on the vegetative growth of many plants (e.g., cotton, wheat) are greater than on seed or fiber production. Normally, salinity suppresses top growth more than root growth. The type of rootstock of woody plants may also affect the specific tolerance of fruit crops to salinity.

Mechanisms of salt tolerance

Mechanisms of salt tolerance take place at three levels of organization: whole plant, cellular and molecular.

Control at the whole plant level

Physiological mechanisms conferring exclusion that operate at the cellular and whole plant level have been reviewed (Greenway and Munns, 1980; Lauchli, 1984; Munns *et al*., 1983; Pitman, 1984; Storey and Walker, 1990) and with particular reference to selectivity for K^+ over Na^+ (Jeschke, 1984; Jeschke and Hartung, 2000). Salt tolerance depends on the ability of the plant to control the transport of salt at five sites, as summarized by Munns *et al*. (2002).

1. Selectivity of uptake by root cells.

It is still unclear which cell types control the selectivity of ions from the soil solution. The initial uptake of Na^+ and Cl^- could occur at the epidermis, at the exodermis, or if soil solution flows apoplastically across the root cortex, it would occur at the endodermis.

2. **Loading of the xylem.**

There is evidence for a preferential loading of K^+ rather than Na^+ by the cells of the stele.

3. **Removal of salt from the xylem in the upper part of the roots, the stem, petiole or leaf sheaths.**

In many species Na^+ is retained in the upper part of the root system and in the lower part of the shoot, indicating an exchange of K^+ for Na^+ by the cells in the stele of the roots or in the vascular bundles in stem and petioles.

4. **Loading of the phloem.**

There is little retranslocation of Na^+ or Cl^- in the phloem, particularly in the more tolerant species. This ensures that salt is not exported to growing tissues of the shoot.

5. **Excretion through salt glands or bladders.**

Only halophytes have well-developed mechanisms to control the uptake, transport and excretion of salt. Glycophytes rely on the first three mechanisms, and exhibit these mechanisms to various degrees. Genetic variation within a given species, or between closely related species, has in most cases been identified as due to different degrees of control of salt uptake by roots, or in loading of the xylem.

There are contributory features that function to maintain low rates of salt accumulation in leaves. High shoot:root ratios and high intrinsic growth rates (Pitman, 1984), and absence of an apoplastic pathway in roots (Garcia *et al*., 1997),

all will serve to reduce the rate at which salt enters the transpiration stream and accumulates in the shoot.

Control at the organelle level: ion compartmentation

There is no evidence of adaptations in enzymes to the presence of salt (reviewed by Munns *et al*., 1983), so mechanisms for salt tolerance at the cellular level involve keeping the salt out of the cytoplasm, and sequestering it in the vacuole of the cell. That this occurs in most species is indicated by the high concentrations found in leaves that are still functioning normally, concentrations well over 200mM, while it is found that these same concentrations will completely repress enzyme activity *in vitro* (Munns *et al*., 1983). Generally Na^+ starts to inhibit most enzymes at concentration above 100 mM. The concentration at which Cl^- becomes toxic is less well defined, but is probably in the same range as that for Na^+. If Na^+ and Cl^- are sequestered in the vacuole of the cell, K^+ and organic solutes should accumulate in the cytoplasm and organelles to balance the osmotic pressure of the ions in the vacuole. The organic solutes that accumulate most commonly under salinity are proline and glycine betaine, although other molecules can accumulate to lesser degrees (Hasegawa *et al*., 2000).

Control at the molecular level: ion transporters

The ion channels and transporters that regulate the net movement of salt across cell membranes have been recently reviewed (Amtmann and Sanders, 1999; Blumwald, 2000; Schachtman and Liu, 1999; Tyerman and Skerrett, 1999). The mechanisms that control Na^+ transport were summarized by Munns *et al*. (2002). There is no

specific Na^+ transporter, Na^+ entry being gained by competition with other cations, in particular K^+. Na^+ could enter the cell through high affinity K^+ carriers or through low affinity channels called non selective cation channels that are strongly influenced by Ca^{2+}. These cation channels could allow entry of large amounts of Na^+ from a highly saline soil if not adequately regulated (Amtmann and Sanders, 1999). Na^+ can be effluxed from the cytoplasm trough Na^+/H^+ antiporters, driven by the pH gradient across the plasmalemma (Blumwald, 2000). These transport processes all work together to control the rate of net uptake of Na^+ by a cell. Intracellular compartmentation is by a vacuolar Na^+/H^+ antiporter, driven by a pH gradient across the tonoplast (Blumwald, 2000). The transporters that maintain low Na^+ concentrations in organelles such as chloroplasts and mitochondria are not known. In some species Cl^- transport is associated with salt tolerance. Mechanisms that control Cl^- movement across membranes have been comprehensively reviewed by White and Broadley (2001).

Diversity in salt tolerance between species

Salt tolerance is usually assessed as the percent biomass production in saline versus control conditions over a prolonged period of time. Munns *et al.* (2002) compared the growth of salt-stressed plants of lupin (one of the most salt-sensitive crop species), barley (one of the most tolerant), as well as two halophytes that are useful forage in salt-affected soils. Plants of these four species were grown under a range of salinity levels. The results suggested that in a field where the salinity rises to 100 mM NaCl (about 10 dS m^{-1}), lupins, and in fact most legume species, will die before maturity, while crops such as wheat and barley will produce a reduced yield. Even

barley dies at salt concentrations higher than 250mM NaCl (about 25 dS m^{-1}, or 50% seawater). Only halophytes will cope with soils where the watertable has brought salt to the surface, as the water in the topsoil will contain salts at concentrations higher than seawater.

The effects of salinity on barley and lupin probably span the extremes of salt tolerance of crops. Wheat (*Triticum aestivum*) is usually considered less tolerant than barley, but there is such difference between genotypes that it is difficult to make a categorical statement. Bean (*Phaseolus vulgaris*) is one of the most salt sensitive species, but for this species, like so many, the supply of additional Ca^{2+} is crucial for the salt tolerance (Layahe and Epstein, 1971), and again it is difficult to generalise. Rice (*Oryza sativa*) is regarded as one of the more salt-sensitive crops, which is certainly true when grain yield is considered (Khatun *et al*., 1995; Maas and Hoffman, 1977). However, vegetative growth of some rice cultivars can be surprisingly tolerant of salinity, at least when adequate Ca^{2+} is supplied (Muhammed *et al*., 1987).

Another criterion of salt tolerance of crops is their yield in saline versus non-saline conditions. A survey of salt tolerance of crops, vegetables and fruit trees has been published by Maas and Hoffman (1977), and updated by Francois and Maas (1994). They show for each species a threshold salinity below which there is no reduction in yield, and then a regression for the reduction in yield with increasing salinity. The data in some cases are for a single cultivar of the species, or a limited number of cultivars at a single site, so they are not necessarily representative of the species.

However, the data are useful in that they show the wide range of tolerance across species, and also show that yield has a different pattern of response than does vegetative biomass. Yield always shows a threshold in response to a range of salinities (Maas and Hoffman, 1977), but with young plants a threshold in growth is rarely seen. With plants exposed to salinity at an early stage of seedling development there are linear reductions in both leaf area expansion and total plant biomass with increasing salinity.

There is probably a great diversity in salt tolerance within species that has not been fully explored. One reason for this is the difficulty of measuring the tolerance of salinity as distinct from the tolerance of water or osmotic stress, and the difficulty of screening large numbers of individuals for small, repeatable and quantifiable differences in biomass production, let alone yield.

Screening for small differences in salt tolerance within species

Differences in salt tolerance between closely related species are difficult to quantify, as the growth reduction depends so much on the period of time over which the plants have grown in saline conditions. Salinity lowers the water potential of the roots, and this quickly causes reductions in growth rate, along with a suite of metabolic changes identical to those caused by water stress (Munns, 2002). Later, there may be salt-specific effects that impact on growth or senescence.

The first few days or weeks in salinity may reveal no differences in growth response between species that have quite different reputations for salt tolerance. For example, durum wheat, *Triticum turgidum* ssp. *Durum* is much more salt-sensitive than bread wheat, *Triticum aestivum* (Francois *et al*., 1986; Rawson *et al*., 1988), yet over short periods of time in salinity there were no differences between durum and bread wheat cultivars (Munns *et al*., 1995). In a comparison between 20 cultivars of wheat, barley and triticale there were no significant differences between the leaf elongation rate in the first 10 days of salinisation of any cultivar, including that of the one that ultimately turned out to be the most sensitive (a durum wheat) and the one (a barley) that turned out to be the most tolerant (Rawson *et al*., 1988). Similar results have been obtained recently with other wheat lines that have a reputation of differing in salt tolerance. Four weeks of growth at 150 mM NaCl was insufficient time for difference in salt tolerance between genotypes to show up (Rivelli *et al*., 2002), including bread and durum wheat cultivars that were known to differ in salt tolerances in the field.

These results are consistent with the concept of a two-phase growth response to salinity (Munns, 1993). The first phase of growth reduction is quickly apparent, and is due to the salt outside the roots. It can be called a water stress or osmotic phase, for which there is surprisingly little genotypic difference. Then there is a second phase of growth reduction, which takes time to develop, and is associated with advanced senescence of older leaves. This presumably results from internal injury due to salts accumulating in these transpiring leaves to excessive levels. If excessive amounts of salt enter a plant, salt will eventually rise to toxic levels in the older transpiring leaves, causing premature senescence and reducing the photosynthetic

capacity of the plant to a level that cannot sustain further growth (Munns, 1993). The cause of the injury is probably due to the salt load exceeding the ability of the cells to compartmentalize salts in the vacuole. Salts then would rapidly build up in the cytoplasm and inhibit enzyme activity. Alternatively, they might build up in the cell walls and dehydrate the cell. Evidence for ions accumulating to high concentrations in the apoplast of leaves has been found in rice (Flowers *et al*., 1991), but not maize (Mühling and Läuchli, 2002).

A two-phase growth response has been shown clearly for maize and wheat cultivars. Two maize cultivars with 2-fold differences in rates of Na^+ accumulation in leaves had the same growth reduction for 15 days in 80 mM NaCl (Cramer *et al*., 1994). Another two maize cultivars, again with 2-fold differences in Na+ accumulation, had the same growth reduction for 4 weeks in 100 mM NaCl, and it was not until 8 weeks that a growth difference was clearly seen (Fortmeier and Schubert, 1995). Similar results were found in wheat (Munns *et al*., 1995). Two closely-related wheat genotypes that differed in rates of Na^+ accumulation had the same growth reduction for 4 weeks in 150 mM NaCl, and it was not until after 4 weeks that a growth difference between the genotypes was clearly seen. However, within 2 weeks dead leaves became visible on the more sensitive genotype, and the rate of leaf death was clearly greater on the sensitive than the tolerant genotype. Once the number of dead leaves increased above about 20% of the total, plant growth slowed down and many individuals started to die (Munns *et al*., 1995). With rice, also, a clear distinction has been made between the initial effects of salinity, from which recovery is possible, and the long-term effects that result from the accumulation of salt within expanded leaves (Yeo *et al*., 1991).

These observations illustrate the principle that the initial growth reduction is due to the osmotic effect of the salt outside the roots, and that what distinguishes a salt-sensitive plant from a more tolerant one is the inability to prevent salt from reaching toxic levels in the transpiring leaves, which takes some time.

The length of time required before growth differences between genotypes can be seen depends on the salinity and the degree of salt tolerance of the species. The second phase will start earlier in plants that are poor excluders of Na^+, such as lupins or beans, and when salinities are higher. It will also start earlier when root temperatures are higher. For plants such as rice that are grown at high temperatures, 10–15 days in salinity is sufficient to generate differences in biomass between genotypes that correlate well with differences in yield (Aslam *et al*., 1993).

The labour and space demands of these long experiments makes this impractical for screening large numbers of genotypes, or selecting salt-tolerant progeny. This means that our knowledge of physiological mechanisms may be used to identify traits that can be employed for rapid and cost-effective selection techniques.

Salinity problem in western Gujarat

The western region of Gujarat state in India can be divided into two zones: (i) the Kutch, a northern saline desert and (ii) the Saurashtra, to the south of the Kutch. The Saurashtra zone includes a peripheral coastal area along the shore of the Arabian Sea and a central area. Intensive agriculture is restricted to the central area, which is

characterized by semi- arid ecoclimate. In the coastal area and saline desert of the Kutch vegetation is sparse mainly because of soil salinity and aridity. Moreover, in coastal area, salt concentration is increasing due to ingress of Arabian Sea. A considerable increase in soil salinity has been recorded in many parts of the central area and also in several other parts of Gujarat state. Groundwater at many places in Gujarat contains excess amount of salt and is not fit for drinking. Evidently, soil salinity is one of the major ecological problems of Gujarat state.

Test plant

Pearl millet *(Pennisetum glaucum* (L.) R. Br.) is a staple food and the primary source of calories for millions of people in the semi-arid tropical regions of the Indian subcontinent and Africa. In India, it is the fourth most important staple food after rice, wheat and sorghum. Pearl millet is a richer source of protein, calcium, phosphorus and iron than some of the other important cereals (Singh *et al*., 1987). Plants of this crop tolerate drought, low soil fertility, low soil pH and respond well to water and favorable soil conditions. Soil salinity greatly hampers pearl millet productivity, delaying germination, reducing seed germination percentage, and severely affecting subsequent growth (Ashraf and Idrees, 1992).

Pearl millet and its wild relatives are rated to be fairly tolerant to salinity (Mass and Hoffman, 1977; Shannon, 1984; Ashraf and McNeilly, 1987) and provide an option while selecting crops that can be more profitably grown in saline soils (Chopra and Chopra, 1993). Large genotypic variation was reported to exist in pearl millet for salinity response in terms of whole plant response (Ashraf and McNeilly, 1987, 1992; Dua, 1989). The availability of high levels of tolerance within the *P. glaucum*

(Dua, 1989) offers a scope for understanding the traits related to tolerance and to integrate these tolerant genotypes into appropriate management programs to improve the productivity of the saline soils.

Aim

The aim of the present investigation was to screen out the genotypes of *P. glaucum* (L.) R. Br. that are salt tolerant and can be profitably grown in saline areas of Saurashtra and Kutch.

Objectives

The objectives of the present study were to assess the following responses of five varieties of Pearl millet (*Pennisetum glaucum*) to soil salinity in order to achieve the aim:

I. Effect of soil salinity on emergence of seedlings
II. Effect of soil salinity on shoot and root elongation and leaf expansion
III. Effect of soil salinity on dry weight accumulation in plant tissues
IV. Effect of soil salinity on water content of plant tissues
V. Effect of soil salinity on water potential of plant tissues
VI. Effect of soil salinity on proline accumulation in plant tissues
VII. Effect of soil salinity on carbohydrate, protein and lipid contents of plant tissues.

VIII. Effect of soil salinity on accumulation of macro- and micro- nutrients in plant tissues.

2.

MATERIAL AND METHODS

MATERIAL AND METHODS

The study area

The present study was carried out in a greenhouse of the botanical garden of Saurashtra University at Rajkot ($22^0$18' N Lat, $70^0$56' E Long) in Gujarat. For the emergence and growth of seedlings the top 15 cm black-cotton soil, which is predominant in Saurashtra region of Gujarat, was collected from an agricultural field. This soil is a clayey loam containing 19.6% sand, 20.3% silt and 60.1% clay. The available soil water between wilting coefficient and field capacity ranged from 18.3% to 35.0%, respectively. The total organic carbon content was 1.3% and pH was 7.2. The electrical conductivity of soil was 0.3 dSm^{-1}. Nitrogen, phosphorus, potassium, calcium, sodium and magnesium contents were 0.15%, 0.05%, 0.03%, 0.05%, 0.002% and 0.08%, respectively. This soil is fertile and fit for intensive agriculture. Physical and chemical properties of soil are given earlier (Patel and Pandey, 2007). Saurashtra region is tropical monsoonic and can be ecoclimatically classified as semi-arid. The entire area is markedly affected by south – western monsoon which causes the onset of wet season in mid – June, and its retreat by the end of September coincides with a lowering of temperature and gradual onset of winter. Total annual rainfall is about 554 mm at Rajkot in central Saurashtra which occurs totally during the rainy season. Typically, there are three main seasons: summer (April – mid June), monsoon (mid June – September) and winter (November – February). The months of October and March are transition periods between rainy (monsoon) and winter and between winter and summer seasons, respectively. Winters are generally mild and summers hot.

Salinisation of soil

Surface soil was collected air dried and passed through a 2 mm mesh screen. Five lots of soil, of 100 kg each, were separately spread, about 50 mm thick, over polyethylene sheets. Sodium chloride (NaCl) amounting to 280, 590, 690 and 1090 g was then thoroughly mixed with soil of four lots, respectively to give electrical conductivities of 3.9, 6.0, 7.9 and 9.8 dS m^{-1}. There was no addition of NaCl to fifth lot of soil that served as control. The electrical conductivity of control soil was 0.3 dS m^{-1} and this value was approximately equal to 3 mM salinity. For the measurement of electrical conductivity a soil suspension was prepared in distilled water at a ratio of 1:2 in terms of weight. The suspension was shaken and allowed to stand overnight. Thereafter, electrical conductivity of the supernatant solution was determined with a conductivity meter. Accordingly five sets of soil were salinised separately for five varieties of test plant.

Verities of *Pennisetum glaucum* (L.) R. Br.

Five genotypes (varieties) of *Pennisetum glaucum* (L.) namely GHB-538, GHB-558, GHB-577, GHB-734 and GHB 743 were studied. Seeds of these genotypes were gently provided by Bajara Research Centre at Jamnagar district in Saurashtra.

Seedling emergence

For a single variety, twenty polyethylene bags for each level of soil salinity were each filled with 5 kg of soil. For five varieties, five sets of bags were filled with soils

varying in salinity. Tap water was added to each bag to bring the soils to field capacity and soils were allowed to dry for 7 days. Soils were then raked using fingers and seeds of five verities were separately sown on 14 August 2005. Bags were kept in a greenhouse. Ten seeds were sown in each bag at a depth of 0-1 mm. Immediately after sowing soils were watered and thereafter watering was carried out on alternate days. Emergence of seedlings was recorded daily over a period of 20 days. Experiment on seedling emergence was repeated next year and seeds were sown on 11 July 2006. A linear model was fitted to cumulative proportion of seed germination (including data of two years experiment) and increasing soil salinity using the expression:

$$Sin^{-1}\sqrt{P} = ß0 + ß1X$$

Where, $Sin^{-1}\sqrt{P}$ is cumulative proportion of seed germination, X is soil salinity and ß0 and ß1 are constants. Salt concentration at which seed germination was reduced to 50% (SG_{50}) was estimated using the model.

Seedling growth

For the growth studies, three seedlings that emerged first were left in each of 20 bags at each level of salinity and others were uprooted. Seedling emergence was only 18% and 20% for GHB-558 and GHB-577 varieties, respectively, at 9.8 dS m^{-1} salinity. Seeds of other three varieties such as GHB-743, GHB-538 and GHB-734 did not germinate when salinity exceeded 7.9 dS m^{-1} . As a result, growth experiments were not conducted on those seedlings that emerged in soils at 9.8 dS m^{-1} salinity. Thus twenty replicates factorialzed with four grades of soil (0.3, 3.9, 6.0

and 7.9 dS m^{-1}) were prepared. This gave a total of 80 bags, which were arranged in twenty randomized blocks, for one variety. Seedlings were watered (to raise the soil moisture to field capacity) at alternate days. For each variety, seedlings contained in 3 bags at each salinity level were harvested at 3, 6, 9 and 12 weeks after sowing. Seedlings were washed to remove soil particles adhered with roots. Morphological characteristics of each seedling were recorded. Shoot height and root length were measured. Leaf area (leaf blade area) was marked out on graph paper. Fresh and dry weights of leaves (leaf blades), stems along with leaf sheath, roots and inflorescences were determined. Water content (g g^{-1} dry weight) in plant tissues (leaves, stems, roots and inflorescences) was calculated using fresh and dry weight values. Experiment on growth studies was conducted for two years (2005 and 2006). Inflorescence emerged after 6-week growth period. Fresh and dry weights of inflorescences were recorded at 9 and 12-week growth stages. Data recorded during two years experiment for morphological characteristics, dry weight and water content of different components were analyzed by two way ANOVA to assess the effect of salinity and age on plant growth.

Functional Growth Analysis (RGR, NAR and LAR)

Values of dry weight of leaves, stems, roots and inflorescences of plants together with leaf area were used to calculate RGR, NAR and LAR as follows.

Relative Growth Rate (RGR) = $\frac{\log W'' - \log W'}{t'' - t'}$

Where, W" and W' are plant dry weights at time t" and t'.

Net Assimilation Rat (NAR) = $\frac{\log L'' - \log L' (W'' - W')}{(L'' - L')(t'' - t')}$

Where W", L" and W', L' are plant dry weight and leaf area, respectively at time t" and t'.

Leaf Area Ratio (LAR) = $\frac{\text{Leaf area in cm}^2}{\text{plant dry weight in mg}}$

Determination of water potential and proline content

At each harvest, plants contained in two bags at each level of salinity were used for measurement of water potential and proline estimation in plant tissues. These measurements were taken only for the plants grown during the second year experiment. Water potential of leaves, stems, roots and inflorescences was measured by Dewpoint Potential Meter WP4. Concentration of proline in plant tissues was estimated following Bates *et al*., (1973). Extract of 0.5 g fresh plant material with aqueous sulphosalicylic acid was prepared. The extracted proline was made to react with ninhydrin to form chromophore and read at 520 nm. Data were analyzed by two way ANOVA.

Estimation of total Carbohydrate

Additional plants for all the varieties were grown at each level of soil salinity and used for carbohydrate, lipid and protein analyses. Total carbohydrate was measured following Hedge and Hofreiter (1962). Plant sample was hydrolysed with 2.5N HCl

into single sugars. In hot acidic medium glucose was dehydrated to hydroxymethyl furfural. This compound with anthrone formed a green coloured product and the colour was read at 630 nm. Data were analysed by two way ANOVA.

Estimation of Protein

Total protein was estimated following Lowery *et al*. (1951). Fresh plant sample amounting to 500 mg was ground with pestle and mortar in 5 – 10 ml of the buffer. Extract was centrifuged and supernatant was used for protein estimation. Sample extract was taken into test tubes and reagents C and D prepared following protocol were mixed. Test tubes were incubated for 30 minutes in dark. Blue colour developed that was read at 660 nm. Data were analysed by two way ANOVA.

Estimation of Lipid

The plant material was extracted with sodium sulphate and chloroform : methanol mixture. This was again treated with 1% NaCl. Solvent was evaporated in waterbath at 50°C and the weight of total lipid was recorded following Jayaraman (1981). Data were analysed by two way ANOVA.

Mineral analyses of plant materials

Mineral analyses were performed on leaves, stems, roots and inflorescences tissues. Plant parts of the seedlings grown in soil at same level of salinity during two years

experiment were pooled separately. Plant samples were ground using mortar and pestle. Three subsamples of plant tissues were analyzed. Total nitrogen was determined by Kjeldahl method and phosphorus content estimated by the chlorostannous molybdophosphoric blue colour method in sulphuric acid (Piper, 1944). Concentrations of Ca, Mg, Na, K, Zn, Fe, Mn and Cu were determined by atomic absorption spectroscopy after triacid (HNO_3: $H2SO_4$: $HClO_4$ in the ratio of 10: 1: 4) digestion. Mineral data were analyzed by two way ANOVA. Correlations and linear regression equations between mineral content and salt concentrations were determined.

3.

RESULTS

RESULTS

Effect of Salinity on Seedling Emergence

Values of seedling emergence under the control and salt-stressed conditions were separately averaged on the data of two years experiment and are presented below:

Variety GHB 538

Emergence of seedlings was noted 2 days after sowing and 94% seeds germinated over a period of 13 days under control (0.3 dS m^{-1} salinity) conditions (Fig. 1). Seedling emergence in saline soils also began 2 days after sowing. Emergence continued for 13, 13 and 13 days in soils at 3.9, 6.0 and 7.9 dS m^{-1} salinities, respectively and corresponding seed germination was 46.5%, 35.5% and 29.5%. Increasing salt concentration caused a significant reduction ($p<0.01$) in seed germination. There was a negative relationship between proportion of cumulative seed germination and concentration of salt according to the following expression: $Y= 75.15-6.03X$, ($R^2_{Adj} = 0.900$, $p<0.01$), where Y is arcsine (degrees) of proportion of cumulative seed germination and X is salt concentration.

Variety GHB 558

Seedlings began to emerge 2 days after sowing and 92% seed germination was obtained over a period of 11 days under control (0.3 dS m^{-1} salinity) conditions (Fig. 2). Seedling emergence in saline soils was also recorded 2 days after sowing.

Emergence lasted for 12, 10 and 11 days in soils with 3.9, 6.0 and 7.9 dS m^{-1} salinities, respectively and corresponding seed germination was 68.5%, 52.5% and 47.5%. There was a significant reduction in seed germination ($p<0.01$) with increasing salt stress. A negative relationship between proportion of cumulative seed germination and concentration of salt was obtained according to the following expression: $Y= 75.14-4.29X$, ($R^2_{Adj} = 0.967$, $p<0.01$), where Y is arcsine (degrees) of proportion of cumulative seed germination and X is salt concentration.

Variety GHB 577

Emergence of seedlings was recorded 2 days after sowing and 66.5% seeds germinated over a period of 13 days under control (0.3 dS m^{-1} salinity) conditions (Fig. 3). Seedling emergence in saline soils also began 2 days after sowing. Emergence continued for 13, 13 and 13 days in soils at 3.9, 6.0 and 7.9 dS m^{-1} salinities, respectively and corresponding seed germination was 47%, 39.5% and 30%. Increasing salt concentration caused a significant reduction ($p<0.01$) in seed germination. There was a negative relationship between proportion of cumulative seed germination and concentration of salt according to the following expression: $Y= 55.72-2.83X$, ($R^2_{Adj} = 0.994$, $p<0.01$), where Y is arcsine (degrees) of proportion of cumulative seed germination and X is salt concentration.

Variety GHB 734

Emergence of seedlings began 2 days after sowing and 67% seed germination was obtained over a period of 11 days under control (0.3 dS m^{-1} salinity) conditions (Fig. 4). Seedling emergence in saline soils was also recorded 2 days after sowing. Emergence lasted for 12, 12 and 13 days in soils with 3.9, 6.0 and 7.9 dS m^{-1} salinities, respectively and corresponding seed germination was 40%, 31% and 26%. There was a significant reduction in seed germination ($p<0.01$) with increasing salt stress. A negative relationship between proportion of cumulative seed germination and concentration of salt was obtained according to the following expression: $Y= 54.11-3.17X$, ($R^2_{Adj} = 0.966$, $p<0.01$), where Y is arcsine (degrees) of proportion of cumulative seed germination and X is salt concentration.

Variety GHB 743

Seedlings began to emerge 2 days after sowing and 82.5% seed germination was obtained over a period of 11 days under control (0.3 dS m^{-1} salinity) conditions (Fig. 5). Seedling emergence in saline soils was also recorded 2 days after sowing. Emergence lasted for 12, 13 and 12 days in soils with 3.9, 6.0 and 7.9 dS m^{-1} salinities, respectively and corresponding seed germination was 47.5%, 37% and 24%. There was a significant reduction in seed germination ($p<0.01$) with increasing salt stress. A negative relationship between proportion of cumulative seed germination and concentration of salt was obtained according to the following expression: $Y= 66.21-4.82X$, ($R^2_{Adj} = 0.977$, $p<0.01$), where Y is arcsine (degrees) of proportion of cumulative seed germination and X is salt concentration.

Variation among varieties

A two way Analysis of Variance (ANOVA) exhibited a significant ($p<0.01$) difference among varieties for seedling emergence. As a result, varieties GHB 538, GHB 558 and GHB 577 are tolerant to salt stress at seed germination stage, while varieties GHB 734 and GHB 743 are sensitive to salt stress.

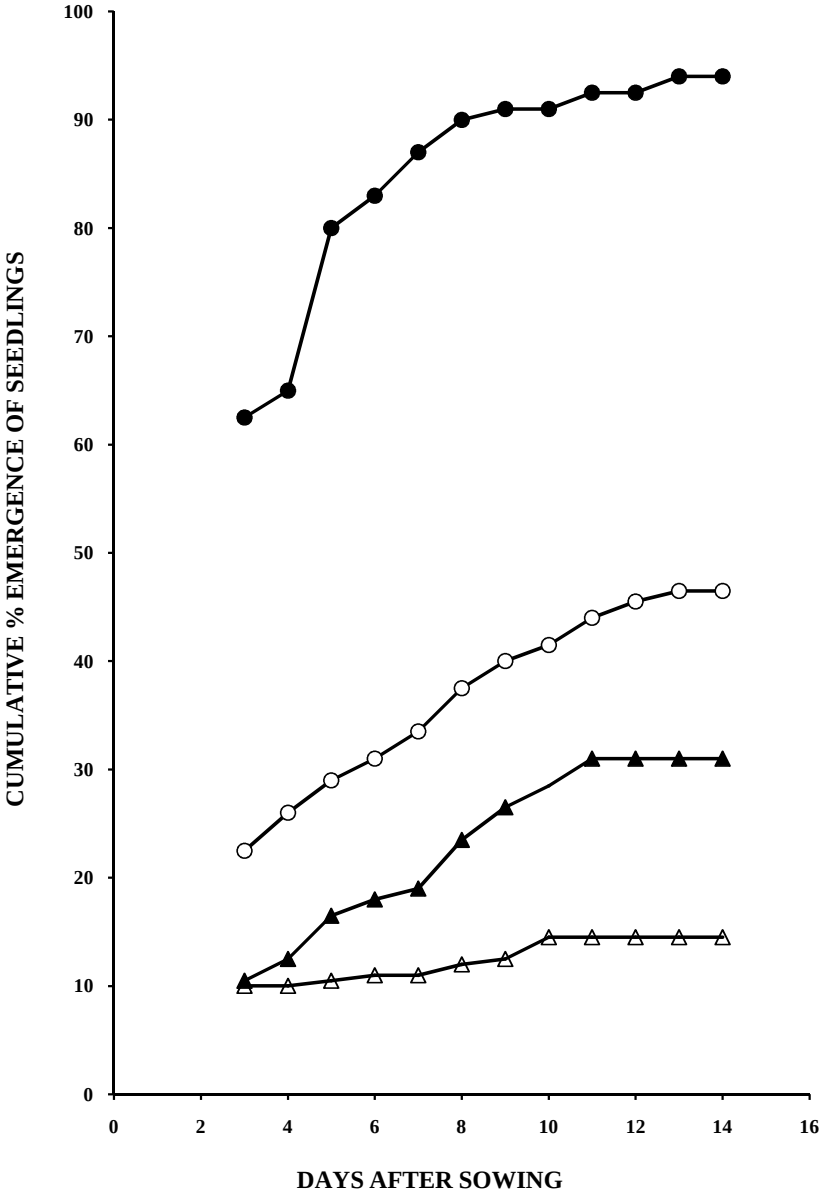

Fig.1. Cumulative emergence of seedlings of *Pennisetum glaucum L.* variety **GHB- 538** in response to soil salinity: (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

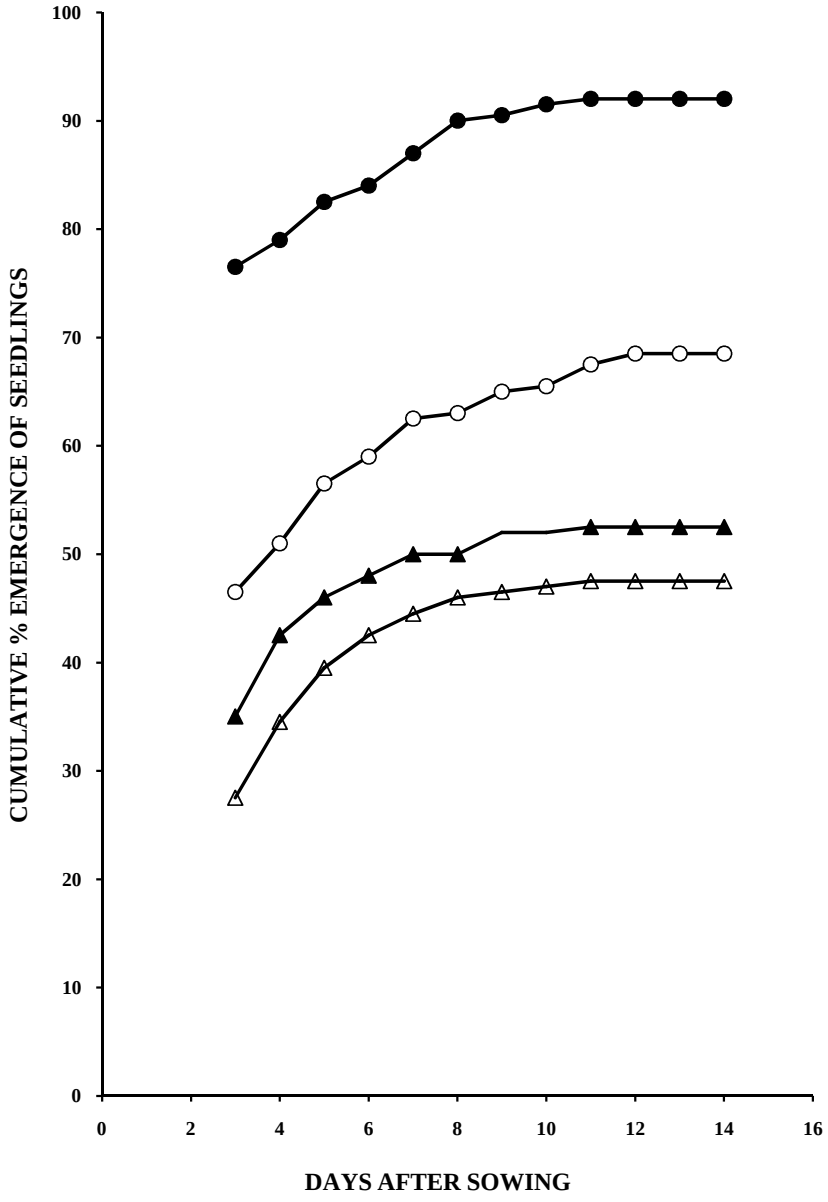

Fig.2. Cumulative emergence of seedlings of *Pennisetum glaucum L.* variety **GHB- 558** in response to soil salinity: (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

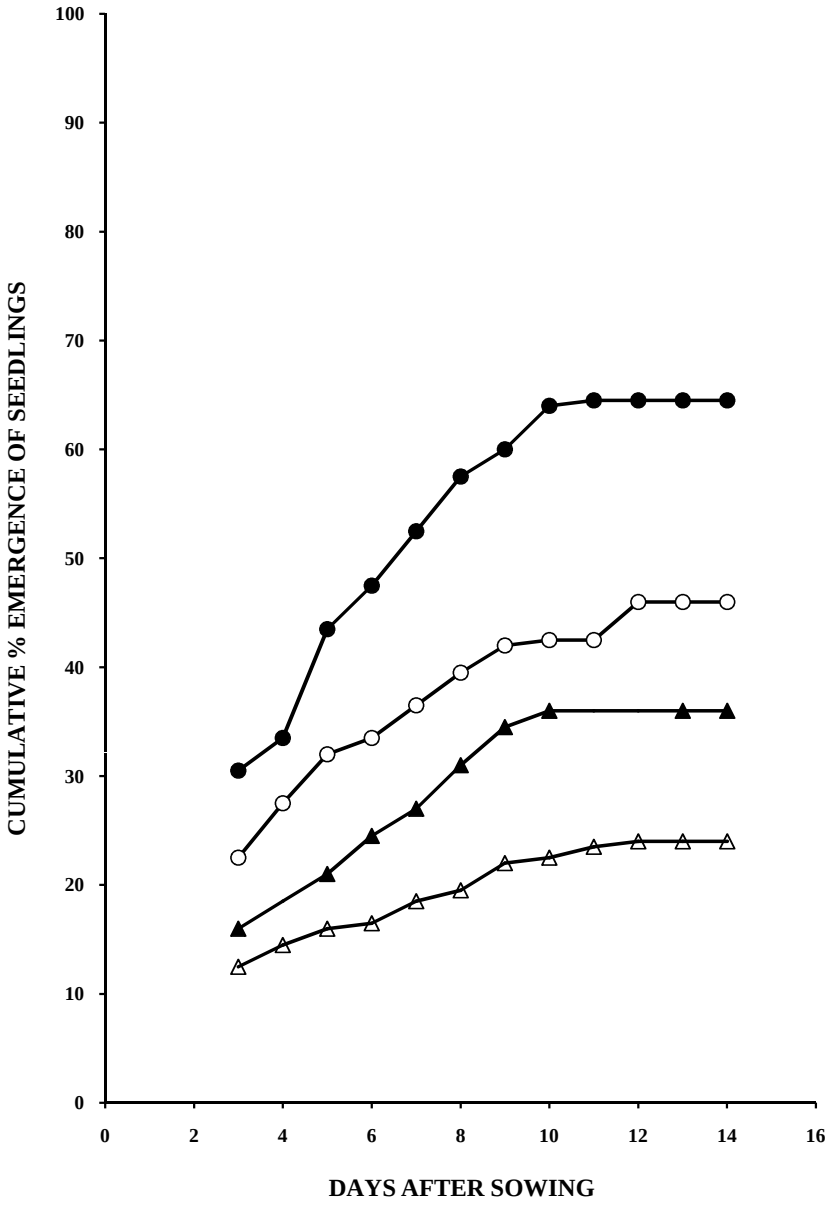

Fig.3. Cumulative emergence of seedlings of *Pennisetum glaucum L.* variety **GHB- 577** in response to soil salinity: (●),0.3dS m^{-1}; (○),3.9dS m^{-1} ; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

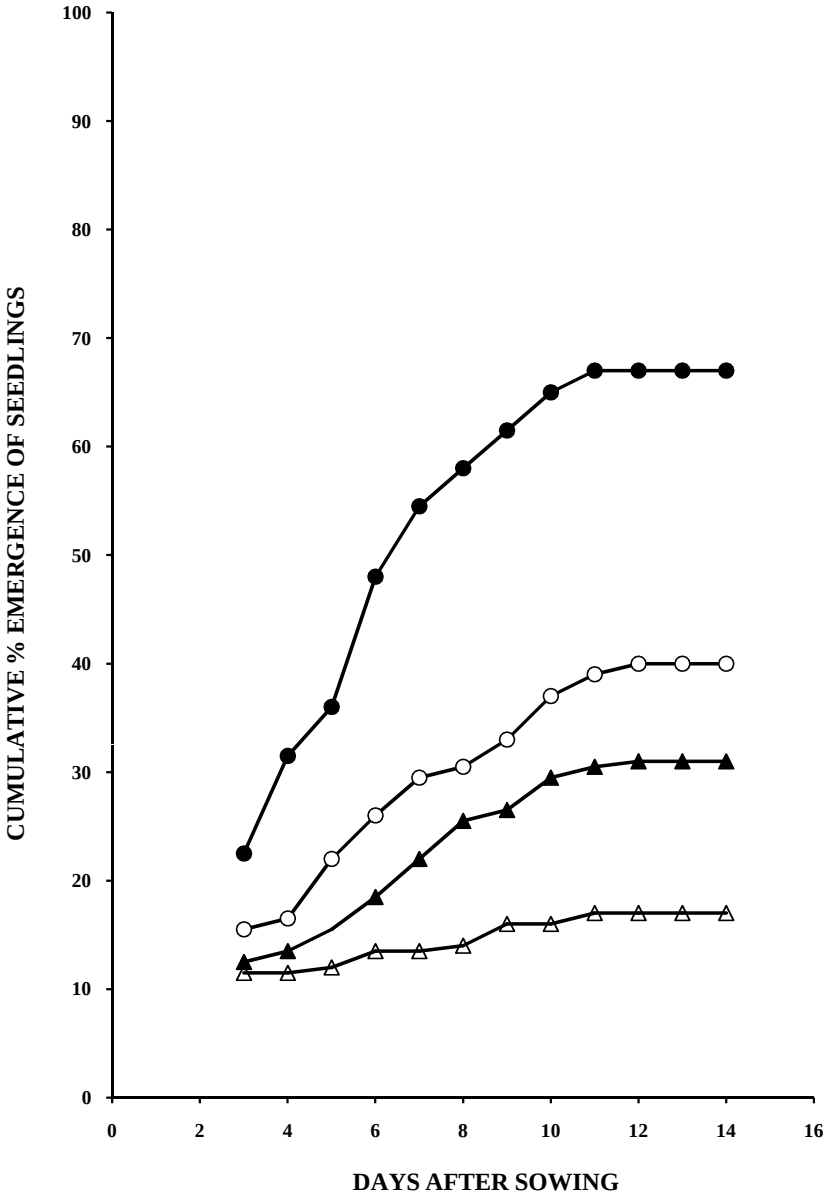

Fig.4. Cumulative emergence of seedlings of *Pennisetum glaucum L.* variety **GHB- 734** in response to soil salinity: (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

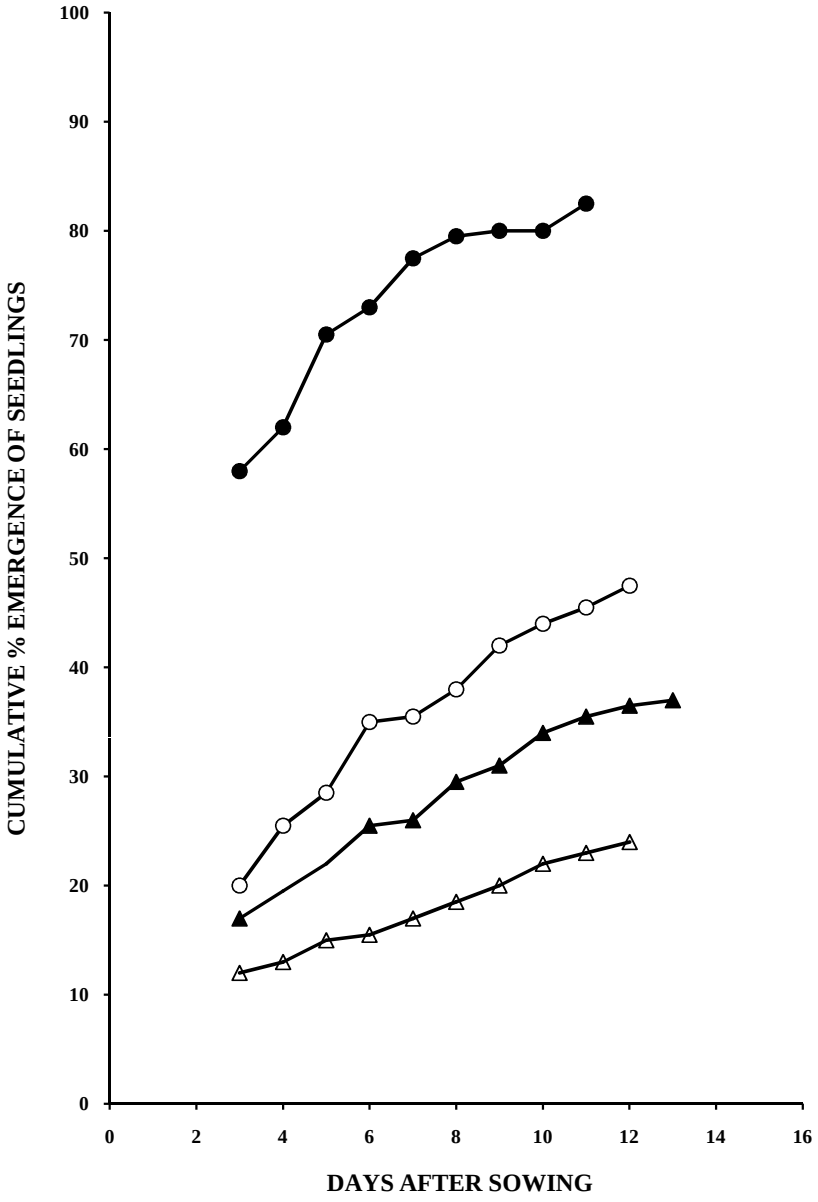

Fig.5. Cumulative emergence of seedlings of *Pennisetum glaucum L.* variety **GHB- 743** in response to soil salinity: (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Effect of Salinity on Stem and Root Elongation and Leaf Expansion

Average values of shoot height, root length and leaf area for control and salt-stressed plants were separately calculated on the data of two years experiment and are presented below:

Variety GHB 538

Shoot height of control as well as salt-stressed plants significantly increased ($p<0.01$) until 12-week growth period (Fig. 6). Increasing concentration of salt significantly retarded ($p<0.01$) the shoot height of plants. Reduction in shoot height of salt-stressed plants as compared to the shoot height of control plants was recorded since the first 3-week growth period. Elongation of shoot was most rapid during 6 to 9-week growth period for both control and salt-stressed plants. There was a negative relationship between shoot height at 12-week growth period and soil salinity according to the following expression:

$Y = 46.69 – 1.31X$ ($r = -0.487$, $p<0.01$, $df = 71$)

Where Y is shoot height (cm) and X is soil salinity (dS m^{-1}).

Root elongation for control as well as salt stressed plants exhibited a trend similar to shoot elongation (Fig. 6). Root elongation significantly increased ($p<0.01$) for control as well as salt-stressed plants as the age of plants advanced. Root length significantly decreased ($p<0.01$) with increasing soil salinity. Elongation of root for both control and salt-stressed plants was most rapid during the initial 3-week growth

period. A negative relationship between soil salinity and root length at 12-week growth stage was obtained according to the following expression:

$Y = 26.60 – 1.16X$ ($r = - 0.578$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity (dS m^{-1}).

Leaf area of control as well as of salt-stressed plants significantly increased ($p<0.01$) until 12-week growth period (Fig. 6). Moreover, leaf area of salt-stressed plants significantly decreased ($p<0.01$) with increase in soil salinity. Leaf expansion for control as well as salt-stressed plants was most rapid during the first 3-week growth period. There was a negative relationship between soil-salinity and leaf area at 12-week growth stage according to the following expression:

$Y = 15.96 – 0.83X$ ($r = - 0.587$, $p<0.01$, $df = 71$)

Where Y is leaf area (cm^2) and X is soil salinity (dS m^{-1}).

Variety GHB 558

Height of shoots of control as well as salt-stressed plants significantly increased ($p<0.01$) with time till 12-week growth period (Fig. 7). Moreover, increasing concentration of salt significantly retarded ($p<0.01$) the shoot height of plants. Shoot height of salt-stressed plants as compared to that of control plants was lower since the initial 3-week growth period. Elongation of shoot was most rapid between 3 to 6-week growth period for the plants grown in soils at 0.3 dS m^{-1} and 3.9 dS m^{-1} salinity. Plants grown in soils at 6.0 dS m^{-1} and 7.9 dS m^{-1} salinity exhibited most rapid shoot elongation during 6 to 9-week growth stage. There was a negative

relationship between soil salinity and shoot height at 12-week growth period according to the following expression:

$Y = 50.17 – 2.92X$ ($r = - 0.807$, $p<0.01$, $df = 71$)

Where Y is shoot height (cm) and X is soil salinity (dS m^{-1}).

Pattern of root elongation for control as well as salt-stressed plants was almost similar to that of shoot elongation (Fig. 7). Root elongation significantly increased ($p<0.01$) for control as well as salt-stressed plants as the age of plants increased. Root length significantly decreased ($p<0.01$) with increasing soil salinity. Elongation of root was most rapid for control as well as salt-stressed plants during the first 3-week growth period. A negative relationship between soil salinity and root length at 12-week growth stage was obtained according to the following expression:

$Y = 23.45 – 0.92X$ ($r = -0.456$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity (dS m^{-1}).

Leaf area of control as well as salt-stressed plants significantly increased ($p<0.01$) until 12-week growth period (Fig. 7). Moreover, leaf area of salt-stressed plants significantly decreased ($p<0.01$) with increase in soil salinity. Leaf expansion for control as well as salt-stressed plants was most rapid during the first 3-week growth period. There was a negative relationship between soil salinity and leaf area at 12-week growth stage according to the following expression:

$Y = 18.53 – 1.06X$ ($r = - 0.477$, $p<0.01$, $df = 71$)

Where Y is leaf area (cm^2) and X is soil salinity (dS m^{-1}).

Variety GHB 577

Shoot height of control as well as salt-stressed plants significantly increased ($p<0.01$) with until 12-week growth period (Fig. 8). Increasing concentration of salt significantly retarded ($p<0.01$) the shoot height of plants. There was a reduction in shoot height of salt-stressed plants as compared to the shoot height of control plants since the initial 3-week growth period. Elongation of shoot was most rapid between 3 to 6-week growth period for the plants grown in soil in control condition. Plants grown in salinity exhibited most rapid shoot elongation during 6 to 9-week growth stage. There was a negative relationship between soil salinity and shoot height at 12-week growth period according to the following expression:

$Y = 41.43 – 2.18X$ ($r = - 0.798$, $p<0.01$, $df = 71$)

Where Y is shoot height (cm) and X is soil salinity (dS m^{-1}).

Root elongation for control as well as salt-stressed plants showed a trend almost similar to that of shoot elongation (Fig. 8). Root elongation significantly increased ($p<0.01$) for control as well as salt-stressed plants as the age of plants advanced. Root length significantly decreased ($p<0.01$) with increasing soil salinity. Elongation of root was most rapid during the first 3-week growth period for control as well as salt-stressed plants. A negative relationship between soil salinity and root length at 12-week growth stage was obtained according to the following expression:

$Y = 22.03 – 1.15X$ ($r = -0.664$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity (dS m^{-1}).

Leaf area of control as well as of salt-stressed plants significantly increased ($p<0.01$) till 12-week growth period (Fig. 8). Moreover, leaf area of salt-stressed plants

significantly decreased ($p<0.05$) with increase in soil salinity. Leaf expansion for both control and salt-stressed plants was most rapid during the initial 3-week growth period. There was a negative relationship between soil salinity and leaf area at 12-week growth stage according to the following expression:

$Y = 25.84 – 1.51X$ ($r = - 0.482$, $p<0.01$, $df = 71$)

Where Y is leaf area (cm^2) and X is soil salinity ($dS\ m^{-1}$).

Variety GHB 734

Height of shoots of control as well as salt-stressed plants significantly increased ($p<0.01$) over time till 12-week growth period (Fig. 9). Increasing concentration of salt significantly retarded ($p<0.01$) the shoot height of plants. There was a reduction in shoot height of salt-stressed plants as compared to the shoot height of control plants since the initial 3-week growth period. Elongation of shoot was maximum during 3 to 6-week growth period for both control and salt-stressed plants. Shoot elongation was minimum during 9 to 12-week growth period for plants grown under control as well as saline conditions. There was a negative relationship between soil salinity and shoot height at 12-week growth period according to the following expression:

$Y = 41.68 – 2.99X$ ($r = -0.861$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity ($dS\ m^{-1}$).

Root elongation for control as well as salt-stressed plants exhibited a pattern almost similar to that of shoot elongation (Fig. 9). Root elongation significantly increased

($p<0.01$) for control as well as salt-stressed plants as the age of plants increased. Root length significantly decreased ($p<0.01$) with increasing soil salinity. Elongation of root for control as well as salt-stressed plants was most rapid during the initial 3-week growth period. A negative relationship between soil salinity and root length at 12-week growth stage was obtained according to the following expression:

$Y = 24.86 – 1.28X$ ($r = - 0.639$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity (dS m^{-1}).

Leaf area of control as well as of salt-stressed plants significantly increased ($p<0.01$) till 12-week growth period (Fig. 9). Moreover, leaf area of salt-stressed plants significantly decreased ($p<0.01$) with increase in soil salinity. Leaf expansion for control as well as salt-stressed plants was most rapid during the first 3-week growth period. There was a negative relationship between soil salinity and leaf area at 12-week growth stage according to the following expression:

$Y = 21.61 – 1.49X$ ($r = - 0.543$, $p<0.01$, $df = 71$)

Where Y is leaf area (cm^2) and X is soil salinity (dS m^{-1}).

Variety GHB 743

Height of shoots of control as well as salt-stressed plants significantly increased ($p<0.01$) over time till 12-week growth period (Fig. 10). Increasing concentration of salt significantly retarded ($p<0.01$) the shoot height of plants. Reduction in shoot height of salt-stressed plants as compared to the shoot height of control plants was

recorded since the first 3-week growth period. Elongation of shoot was most rapid between 6 to 9-week growth period for both control and salt-stressed plants. There was a negative relationship between soil salinity and shoot height at 12-week growth period according to the following expression:

$Y = 54.84 – 3.05X$ ($r = - 0.731$, $p<0.01$, $df = 71$)

Where Y is shoot height (cm) and X is soil salinity (dS m^{-1}).

Pattern of root elongation for control as well as salt-stressed plants was almost similar to that of shoot elongation (Fig. 10). Root elongation significantly increased ($p<0.01$) for control as well as salt-stressed plants as the age of plants increased. Root length significantly decreased ($p<0.01$) with increasing soil salinity. Elongation of root was most rapid for control as well as salt-stressed plants during the first 3-week growth period. A negative relationship between root length at 12-week growth stage and soil salinity was obtained according to the following expression:

$Y = 27.96 – 1.65X$ ($r = - 0.727$, $p<0.01$, $df = 71$)

Where Y is root length (cm) and X is soil salinity (dS m^{-1}).

Leaf area of control as well as of salt-stressed plants significantly increased ($p<0.01$) till 12-week growth period (Fig. 10). Moreover, leaf area of salt-stressed plants significantly decreased ($p<0.01$) with increase in soil salinity. Leaf expansion for control as well as salt-stressed plants was most rapid during first 3-week growth stage. There was a negative relationship between soil salinity and leaf area at 12-week growth stage according to the following expression:

$Y = 12.22 – 0.98X$ ($r = - 0.749$, $p<0.01$, $df = 71$)

Where, Y is leaf area (cm^2) and X is soil salinity ($dS\ m^{-1}$).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in respect to shoot and root elongation and leaf expansion in response to salinity.

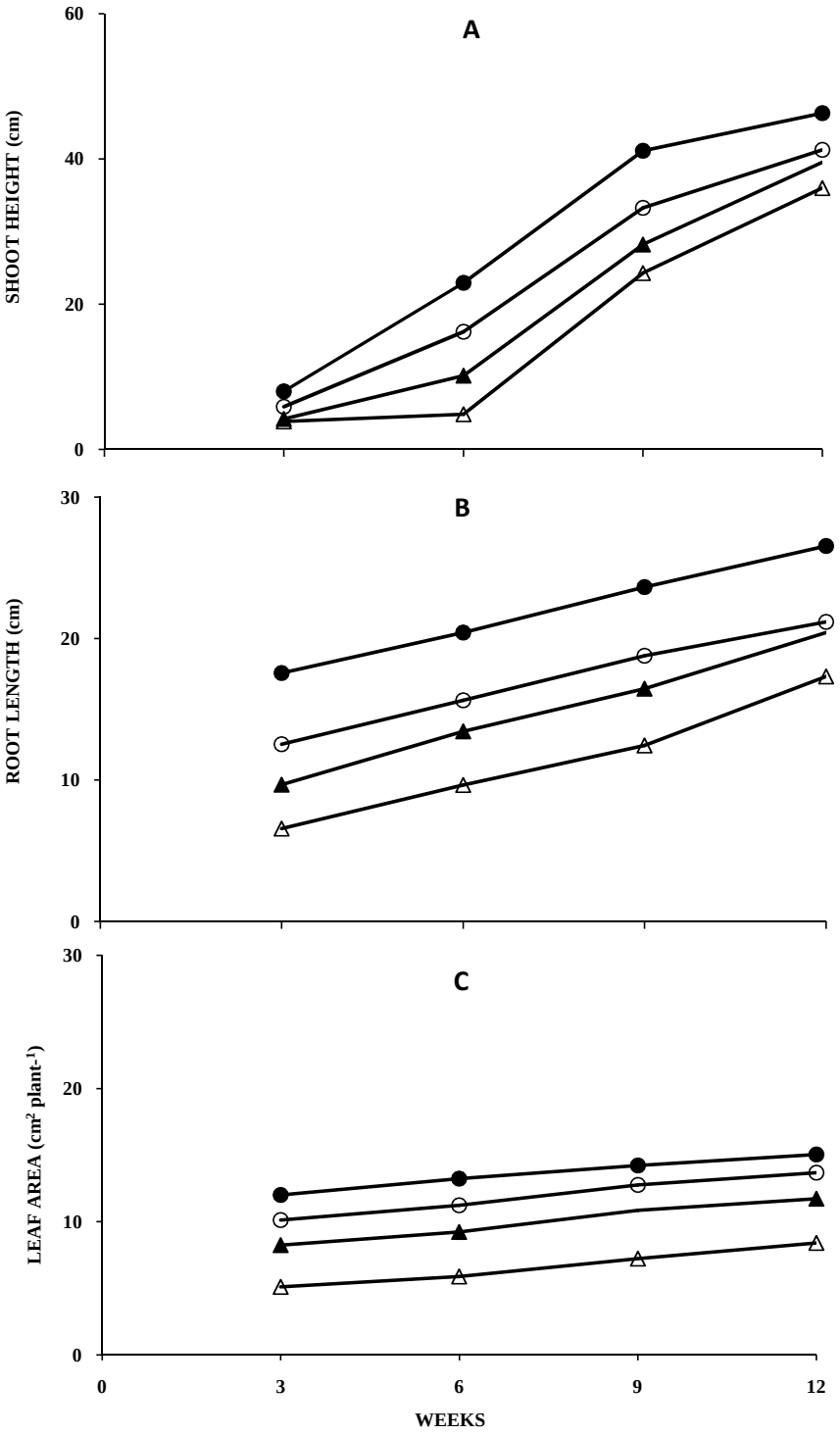

Fig. 6. Effect of soil salinity on **A**.shoot height, **B**.root length and **C**.leaf area of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}.
Error bars represent SE.

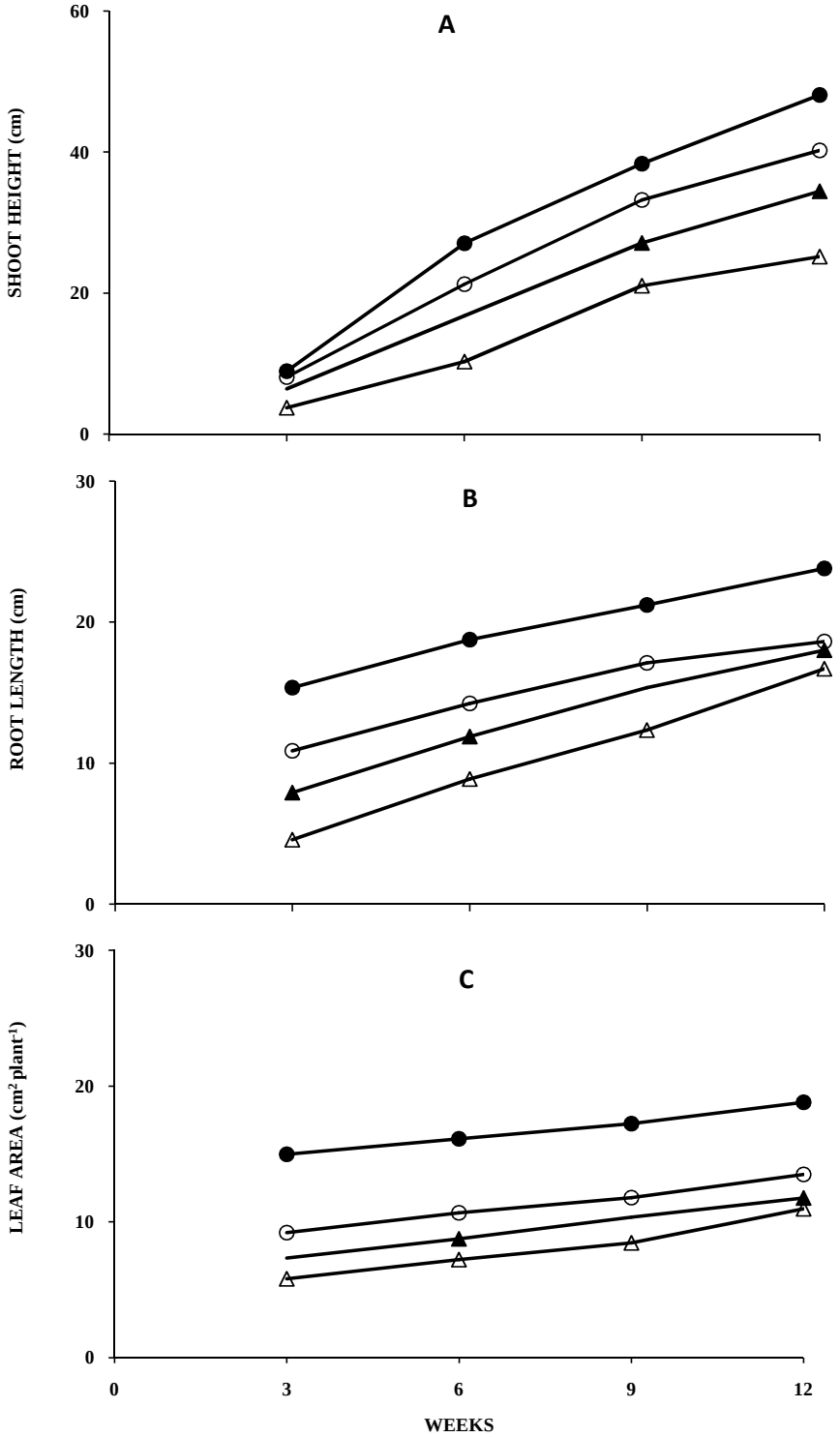

Fig. 7. Effect of soil salinity on **A**.shoot height, **B**.root length and **C**.leaf area of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

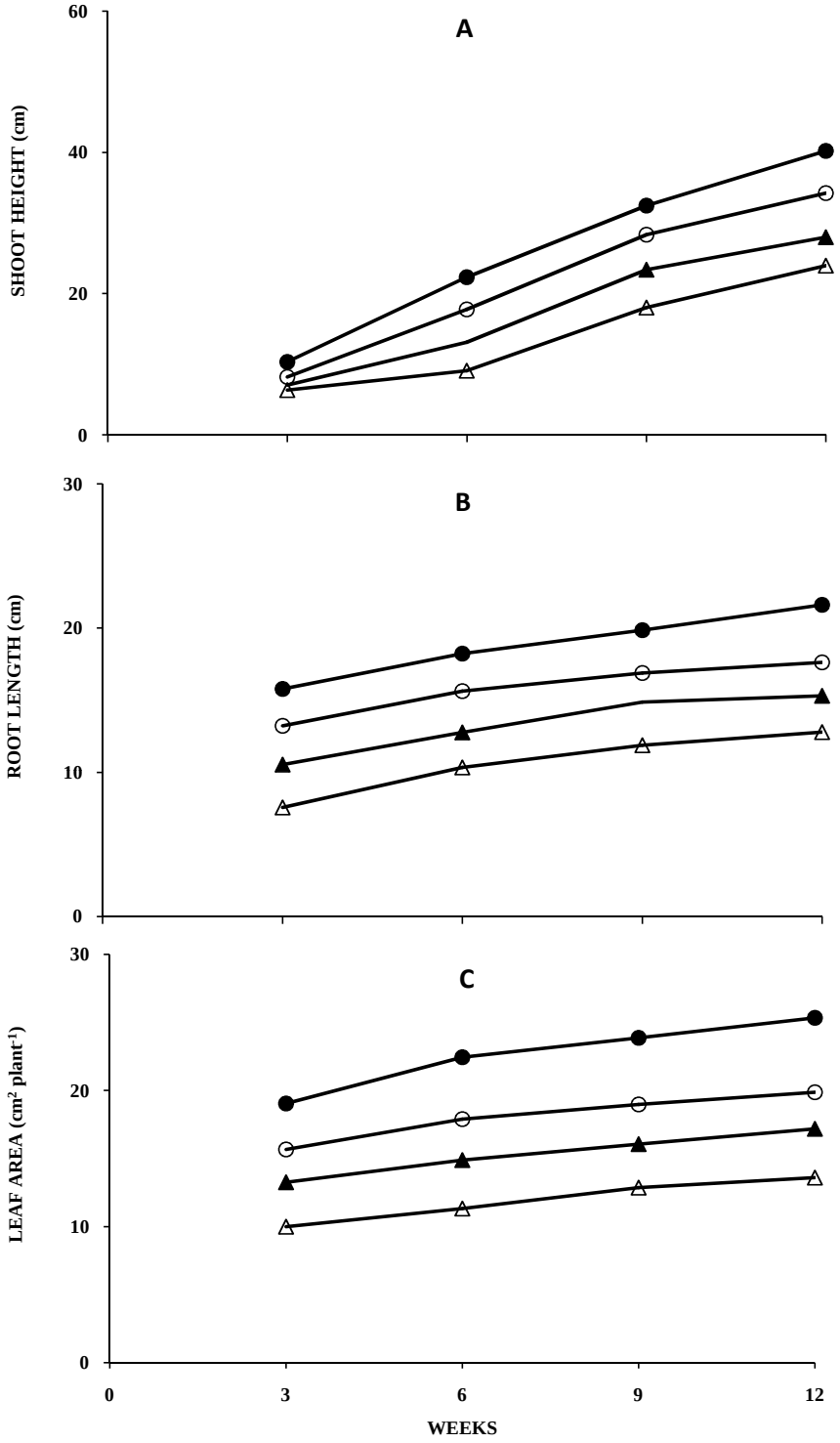

Fig. 8. Effect of soil salinity on **A**.shoot height, **B**.root length and **C**.leaf area of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}.
Error bars represent SE.

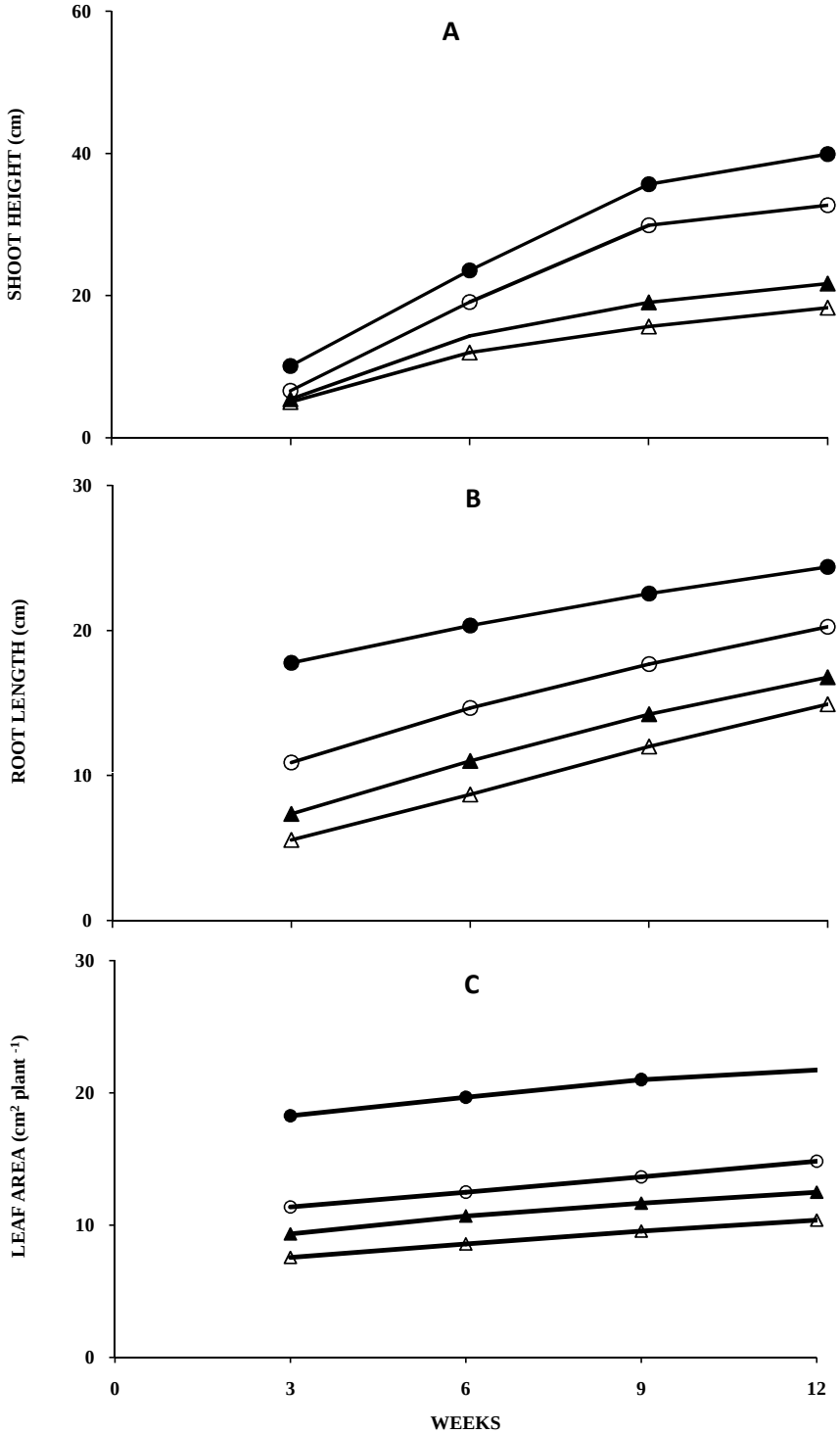

Fig. 9. Effect of soil salinity on **A**.shoot height, **B**.root length and **C**.leaf area of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

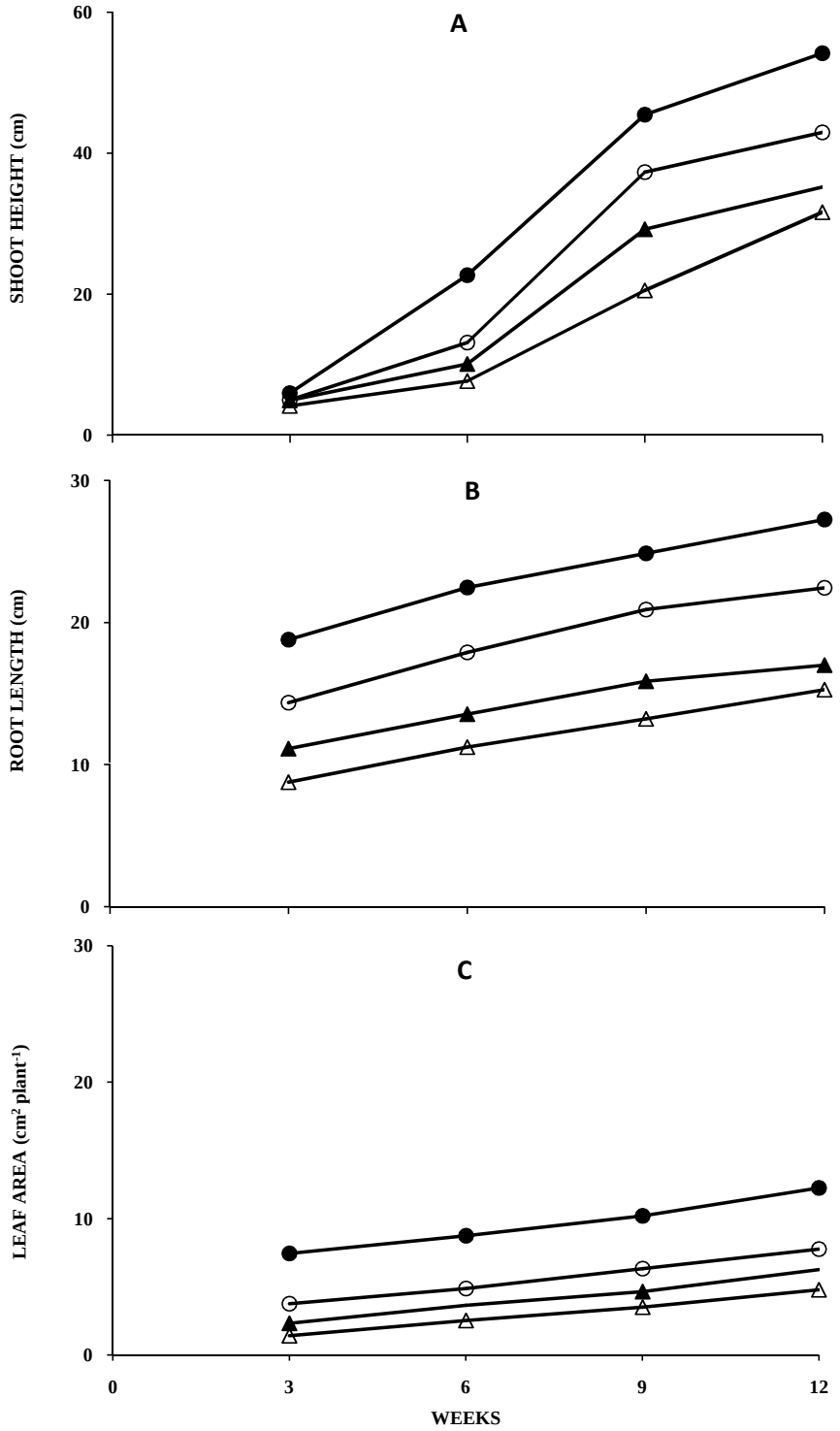

Fig. 10. Effect of soil salinity on **A**.shoot height, **B**.root length and **C**.leaf area of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1} ; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Effect of Salinity on Dry Weight

Dry weight values of leaves, stems, shoots (leaves + stems), roots and inflorescences for control and salt-stressed plants were separately averaged for two years growth experiment and are presented below:

Variety GHB 538

Dry matter accumulation in leaves, stems, shoots (leaves + stems) and roots of control as well as salt-stressed plants significantly increased ($p<0.01$) as the age of plants advanced until 12-week growth period (Fig. 11). Dry matter accumulation in leaves, stems and roots was maximum during the initial 3-week growth period, whereas it was minimum during 9 to 12-week growth period. Increasing salt concentration significantly retarded the growth of leaves, stem, shoots ($p<0.01$) and roots ($p<0.05$). Among the tissues (leaves, stems and roots) of both control and salt-stressed plants dry weight was maximum in leaves and minimum in roots at all the growth stages. Inflorescence weight for control as well as salt-stressed plants increased from 9-week to 12-week growth period (Fig. 11). However, inflorescence weight was retarded ($p<0.01$) by salt concentration. There was a negative relationship between salt concentration in soil and dry weight of leaves, stems, shoots, roots and inflorescences at 12-week growth period according to the following expressions:

Leaf: $Y = 504.52 – 15.08X$ ($r = -0.529$, $p<0.01$, $df = 71$)

Stem: $Y = 313.51 – 18.24X$ ($r = -0.517$, $p<0.01$, $df = 71$)

Shoot: $Y = 818.10 – 33.32X$ ($r = -0.572$, $p<0.01$, $df = 71$)

Root: $Y = 166.73 – 6.43X$ ($r = -0.448$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 406.81 – 17.76X$ ($r = -0.506$, $p<0.01$, $df = 71$)

Where Y is dry weight (mg) and X is concentration of salt in soil (dS m^{-1}).

Root/shoot dry weight ratio for control plant was 0.20 ± 0.02, 0.20 ± 0.01, 0.20 ± 0.01 and 0.21 ± 0.02 at 3, 6, 9 and 12 week growth stages, respectively. Root/shoot dry weight ratio did not change in response to increase in soil salinity.

Variety GHB 558

Dry matter accumulation in leaves, stems, shoots (leaves + stems) and roots for both control and salt-stressed plants significantly increased ($p<0.01$) as the age of plants increased till 12-week growth period (Fig. 12). Rate of dry matter accumulation in leaves, stems and roots was maximum during the initial 3-week growth period, whereas it was minimum during 9 to 12-week growth period. However, salt-stress significantly retarded ($p<0.01$) the growth of plant tissues. Among the tissues (leaves, stems and roots) of both control and salt-stressed plants dry weight was maximum in leaves and minimum in roots at all the growth stages. Inflorescence weight for both control and salt-stressed plants increased from 9-week to 12-week growth period (Fig 12). Salt concentration significantly reduced ($p<0.01$) the weight of inflorescence. There was a negative relationship between salt concentration in soil and dry weight of leaves, stems, shoots, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 443.92 – 9.99X$ ($r = -0.497$, $p<0.01$, $df = 71$)

Stem: $Y = 406.03 – 19.38X$ ($r = -0.407$, $p<0.01$, $df = 71$)

Shoot: $Y = 850.01 – 29.37X$ ($r = -0.499$, $p<0.01$, $df = 71$)

Root: $Y = 214.54 – 10.09X$ ($r = -0.455$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 386.60 – 9.39X$ ($r = - 0.414$, $p<0.01$, $df = 71$)

Where Y is dry weight (mg) and X is concentration of salt in soil (dS m^{-1}).

Root/shoot dry weight ratio for control plant was 0.25 ± 0.02, 0.25 ± 0.02, 0.25 ± 0.02 and 0.27 ± 0.03 at 3, 6, 9 and 12 week growth stages, respectively. Root/shoot dry weight ratio did not change in response to increase in soil salinity.

Variety GHB 577

Dry matter accumulation in leaves, stems, shoots (leaves + stems) and roots of control as well as salt-stressed plants significantly increased ($p<0.01$) as the age of plants advanced until 12-week growth period (Fig 13). Dry matter accumulation in leaves, stems and roots was maximum during the first 3-week growth period, whereas it was minimum during 9 to 12-week growth period. However, growth of plant tissues (leaves, stems, shoots and roots) was significantly ($p<0.01$) retarded by increasing salt concentration in soil. Among the tissues (leaves, stems and roots) of both control and salt-stressed plants dry weight was maximum in leaves and minimum in roots at all the growth stages. Inflorescence weight for control as well as salt-stressed plants increased from 9-week to 12-week growth period (Fig. 13). Salt concentration significantly retarded ($p<0.01$) the weight of inflorescence. There

was a negative relationship between salt concentration in soil and dry weight of leaves, stems, shoots, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 567.73 – 25.04X$ ($r = -0.623$, $p<0.01$, $df = 71$)

Stem: $Y = 405.94 – 22.97X$ ($r = -0.578$, $p<0.01$, $df = 71$)

Shoot: $Y = 993.80 – 48.10X$ ($r = -0.660$, $p<0.01$, $df = 71$)

Root: $Y = 203.51 – 11.30X$ ($r = -0.457$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 367.94 – 8.77X$, ($r = - 0.377$, $p<0.01$, $df = 71$)

Where Y is dry weight (mg) and X is concentration of salt in soil (dS m^{-1}).

Root/shoot dry weight ratio for control plant was 0.20 ± 0.01, 0.21 ± 0.02, 0.20 ± 0.01 and 0.21 ± 0.02 at 3, 6, 9 and 12 week growth stages, respectively. Root/shoot dry weight ratio did not change in response to increase in soil salinity.

Variety GHB 734

Dry matter accumulation in tissues (leaves, stems, shoots (leaves + stems) and roots) for both control and salt-stressed plants significantly increased ($p<0.01$) as the age of plants increased till 12-week growth period (Fig. 14). Dry matter accumulation in leaves, stems and roots was maximum during the initial 3-week growth period, whereas it was minimum during 9 to 12-week growth period. However, growth of plant tissues (leaves, stems, shoots and roots) was significantly ($p<0.01$) retarded by increasing salt concentration in soil. Among the tissues (leaves, stems and roots) of

both control and salt-stressed plants dry weight was maximum in leaves and minimum in roots at all the growth stages. Inflorescence weight for both control and salt-stressed plants increased from 9-week to 12-week growth period (Fig. 14). Salt concentration significantly reduced ($p<0.01$) the weight of inflorescence. There was a negative relationship between salt concentration in soil and dry weight of leaves, stems, shoots, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 592.10 – 29.18X$ ($r = -0.696$, $p<0.01$, $df = 71$)

Stem: $Y = 424.62 – 26.23X$ ($r = -0.562$, $p<0.05$, $df = 71$)

Shoot: $Y = 1016.01 – 55.41X$ ($r = -0.742$, $p<0.01$, $df = 71$)

Root: $Y = 221.82 – 14.38X$ ($r = -0.573$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 512.22 – 38.90X$ ($r = -0.807$, $p<0.01$, $df = 71$)

Where Y is dry weight (mg) and X is concentration of salt in soil (dS m^{-1}).

Root/shoot dry weight ratio for control plant was 0.22 ± 0.02, 0.21 ± 0.02, 0.23 ± 0.02 and 0.22 ± 0.02 at 3, 6, 9 and 12 week growth stages, respectively. Root/shoot dry weight ratio did not change in response to increase in soil salinity.

Variety GHB 743

Dry matter accumulation in leaves, stems, shoots (leaves + stems) and roots for both control and salt-stressed plants significantly increased ($p<0.01$) as the age of plants increased till 12-week growth period (Fig. 15). Rate of dry matter accumulation in leaves, stems and roots was maximum during the initial 3-week growth period,

whereas it was minimum during 9 to 12-week growth period. However, growth of plant tissues (leaves, stems, shoots and roots) was significantly retarded ($p<0.01$) by increasing salt concentration in soil. Among the tissues (leaves, stems and roots) of both control and salt-stressed plants dry weight was maximum in leaves and minimum in roots at all the growth stages. Inflorescence weight for both control and salt-stressed plants increased from 9-week to 12-week growth period (Fig. 15). Salt concentration significantly reduced ($p<0.01$) the weight of inflorescence. There was a negative relationship between salt concentration in soil and dry weight of leaves, stems, shoots, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 558.33 – 34.09X$ ($r = -0.644$, $p<0.01$, $df = 71$)

Stem: $Y = 409.30 – 33.03X$ ($r = -0.717$, $p<0.01$, $df = 71$)

Shoot: $Y = 967.62 – 67.12X$ ($r = -0.821$, $p<0.01$, $df = 71$)

Root: $Y = 215.34 – 14.28X$ ($r = -0.599$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 479.71 – 23.34X$ ($r = - 0.559$, $p<0.01$, $df = 71$)

Where Y is dry weight (mg) and X is concentration of salt in soil (dS m^{-1}).

Root/shoot dry weight ratio for control plant was 0.26 ± 0.07, 0.21 ± 0.01, 0.22 ± 0.02 and 0.22 ± 0.02 at 3, 6, 9 and 12 week growth stages, respectively. Root/shoot dry weight ratio did not change in response to increase in soil salinity.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in dry matter accumulation in tissues (leaves, stems, shoots, roots and inflorescences) in response to salinity.

Percent Relative Weight of tissues

Percent relative weight of tissues of plants grown in soil at 7.9 dS m^{-1} salinity compared to those of control plants at 12-week growth period were computed as (salinised tissues dry weight/control dry weight) × 100. Values of percentage relative weight for leaves were 76.3%, 83%, 63.7%, 57% and 53.4% for varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 respectively. Values of percentage relative weight for stems were 52.2%, 64.5%, 48.7%, 47.2% and 37.7% for varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 respectively. Values of percentage relative weight for roots were 70.9%, 65.2%, 54.1%, 53% and 47.6% for varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 respectively.

Percent Relative Weight of shoots

Percent relative weight of shoots (leaves + stems) of plants grown in soil at 7.9 dS m^{-1} compared to those of control plants at 12-week growth period were computed as (salinised shoot dry weight/ control dry weight) × 100. Values of percentage relative

weight for shoots were 67.2%, 74.3%, 57.5%, 52.8% and 43.1% for varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 respectively.

Percent Relative Weight of the whole plants

Percent relative weight of the whole plants (leaves + stems + roots + inflorescences) grown in soil at 7.9 dS m^{-1} salinity compared to those of control plants at 12-week growth period were computed as (salinised total plant dry weight/control dry weight) × 100. Values of percentage relative weight for the whole plants were 67.8%, 74.4%, 62%, 53.4% and 51.7% for varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 respectively.

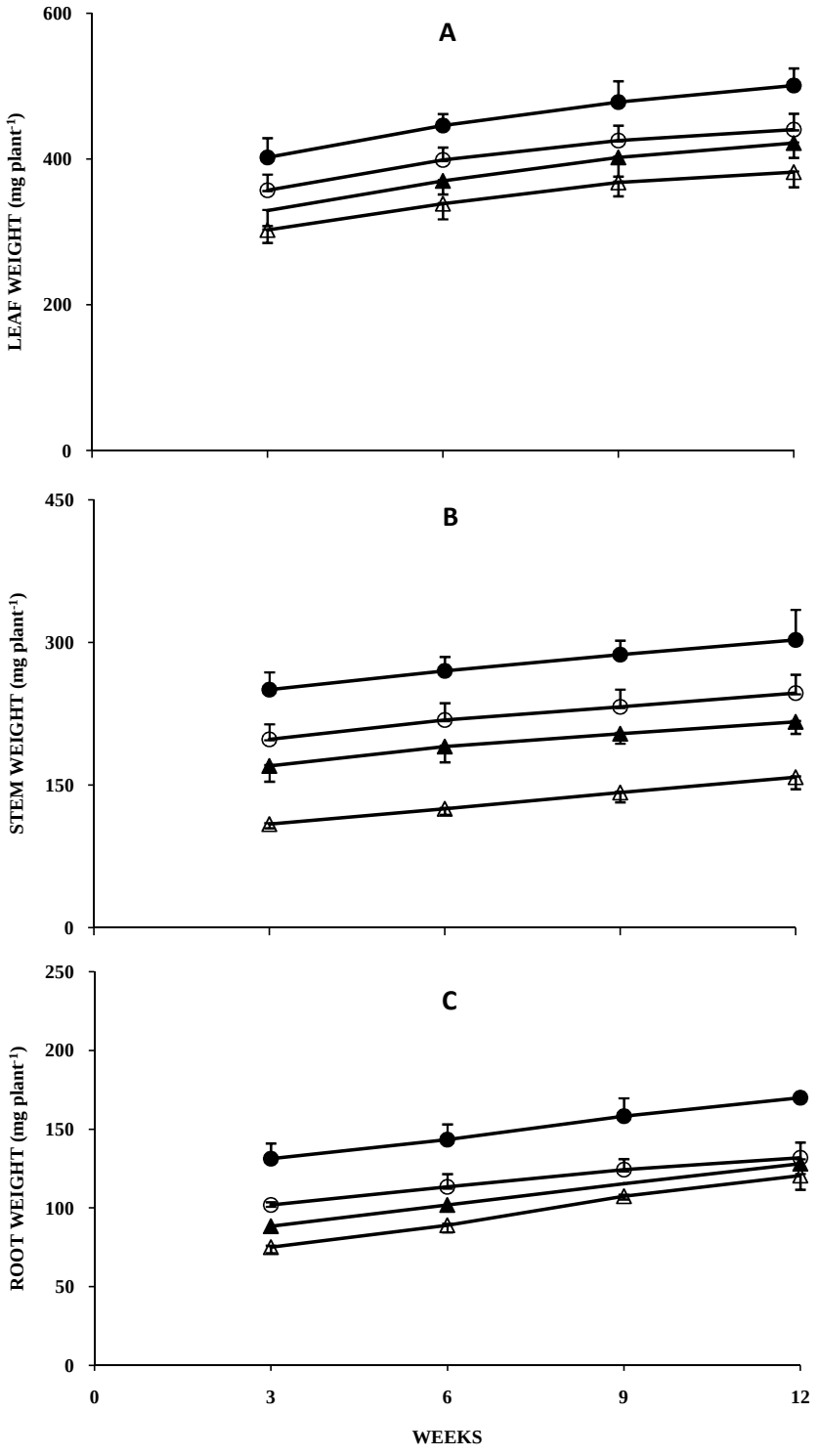

Fig. 11. Effect of soil salinity on dry weight of **A**.leaf, **B**.stem and **C**.root of *Pennisetum glaucum L.* variety **GHB 538** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

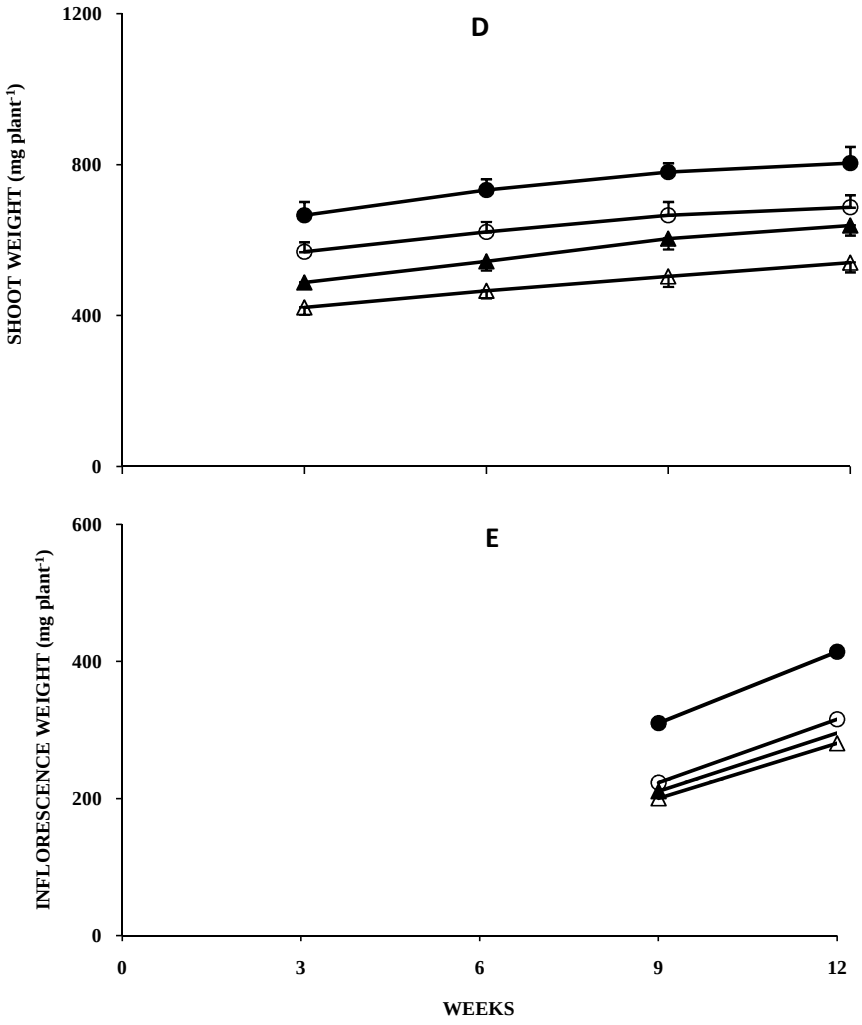

Fig. 11. Effect of soil salinity on dry weight of **D.**shoot and **E.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

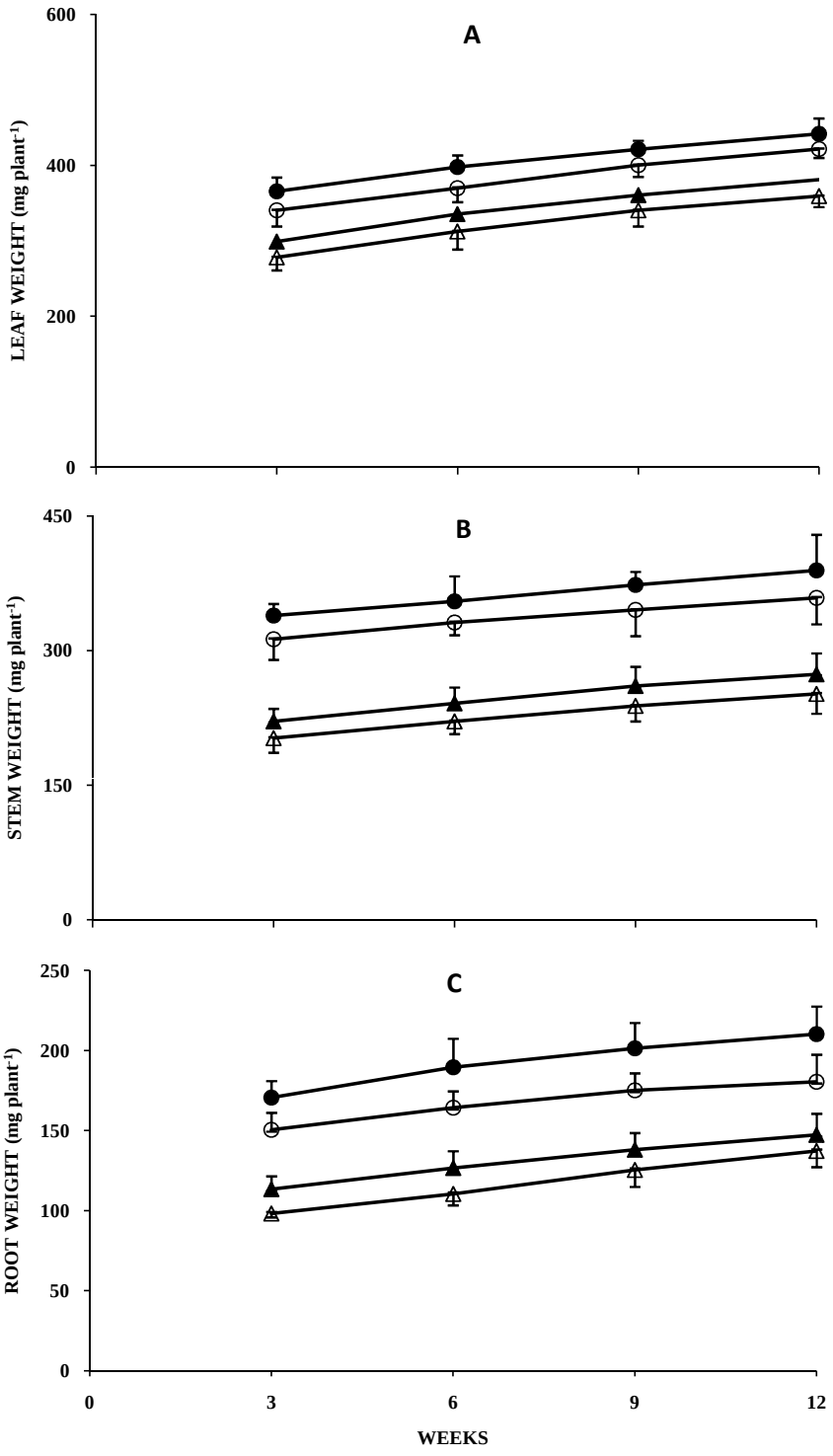

Fig. 12. Effect of soil salinity on dry weight of **A**.leaf, **B**.stem and **C**.root of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

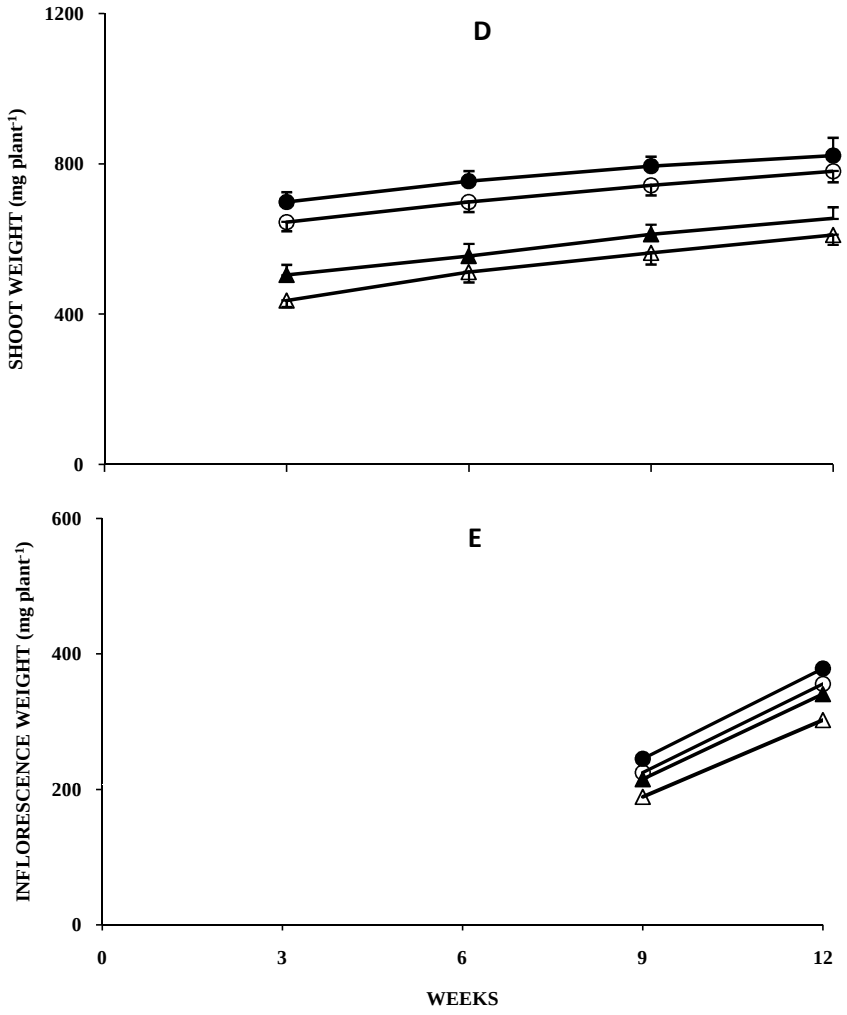

Fig. 12. Effect of soil salinity on dry weight of **D.**shoot and **E.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

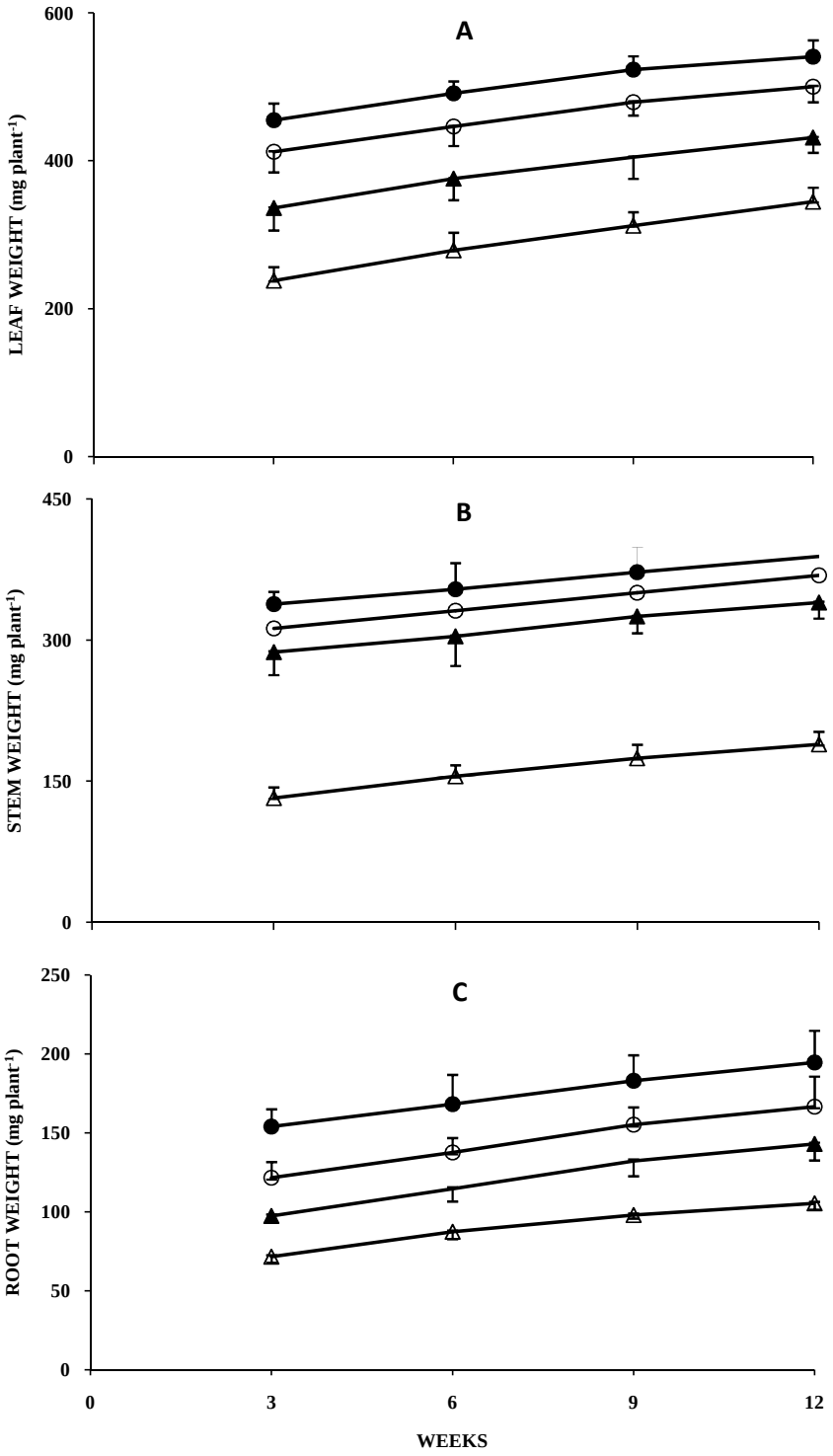

Fig. 13. Effect of soil salinity on dry weight of **A**.leaf , **B**.stem and **C**.root of *Pennisetum glaucum L.* variety **GHB 577** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

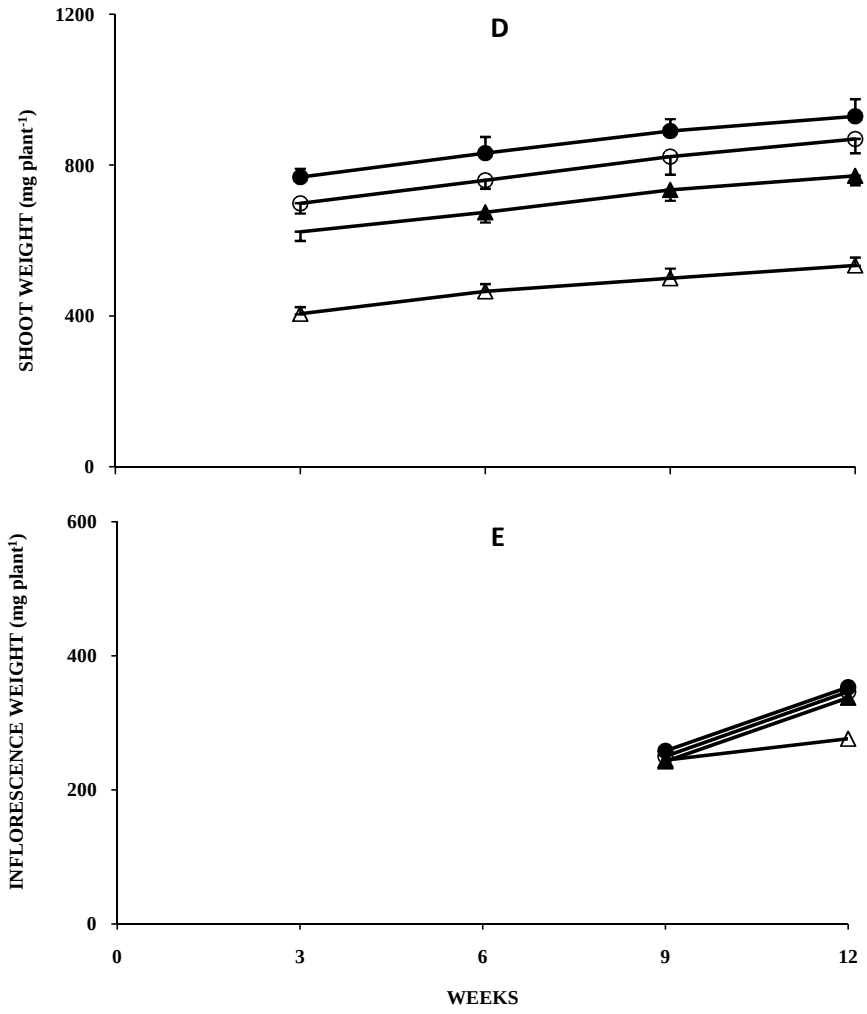

Fig. 13. Effect of soil salinity on dry weight of **D.**shoot and **E.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

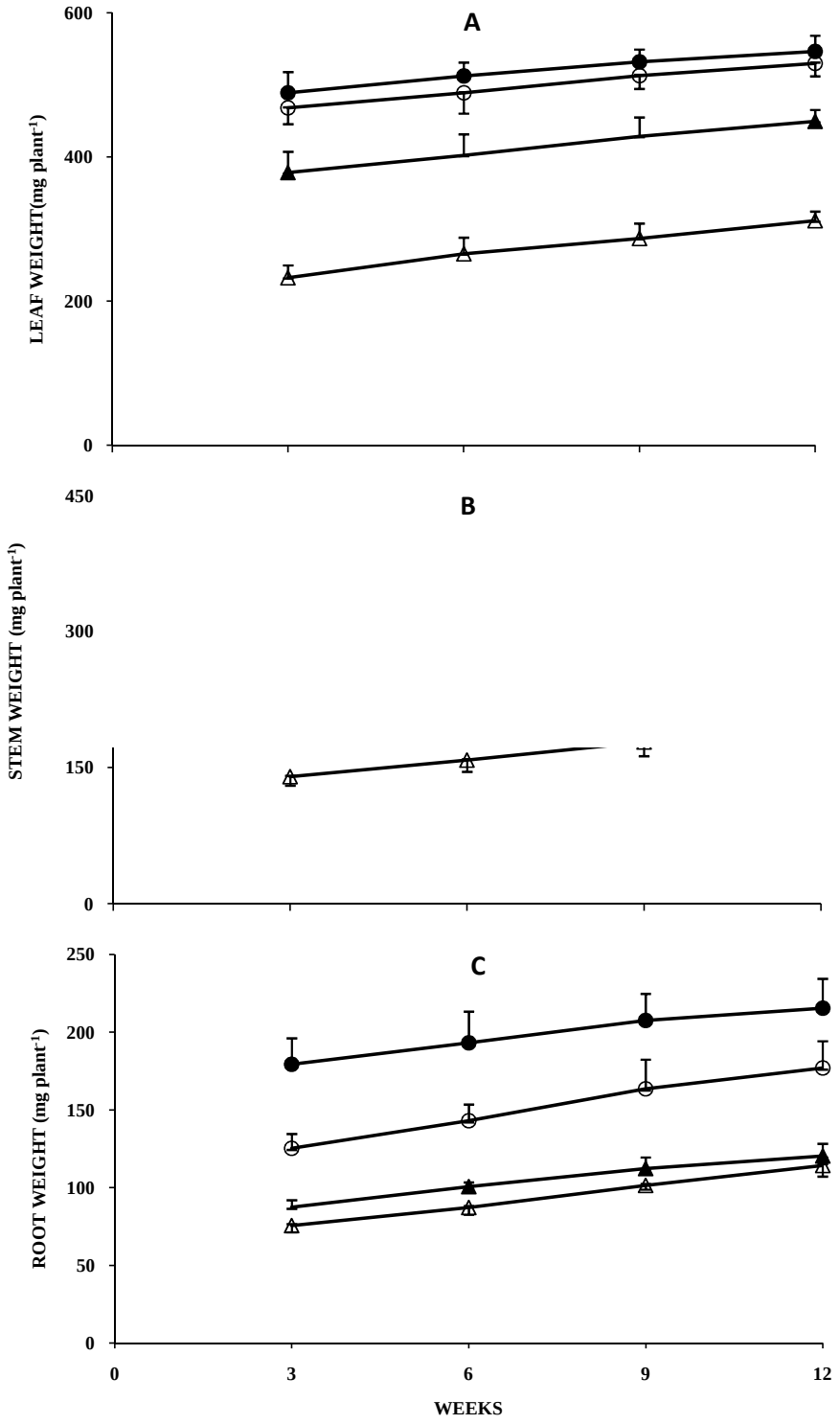

Fig. 14. Effect of soil salinity on dry weight of **A**.leaf, **B**.stem and **C**.root of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

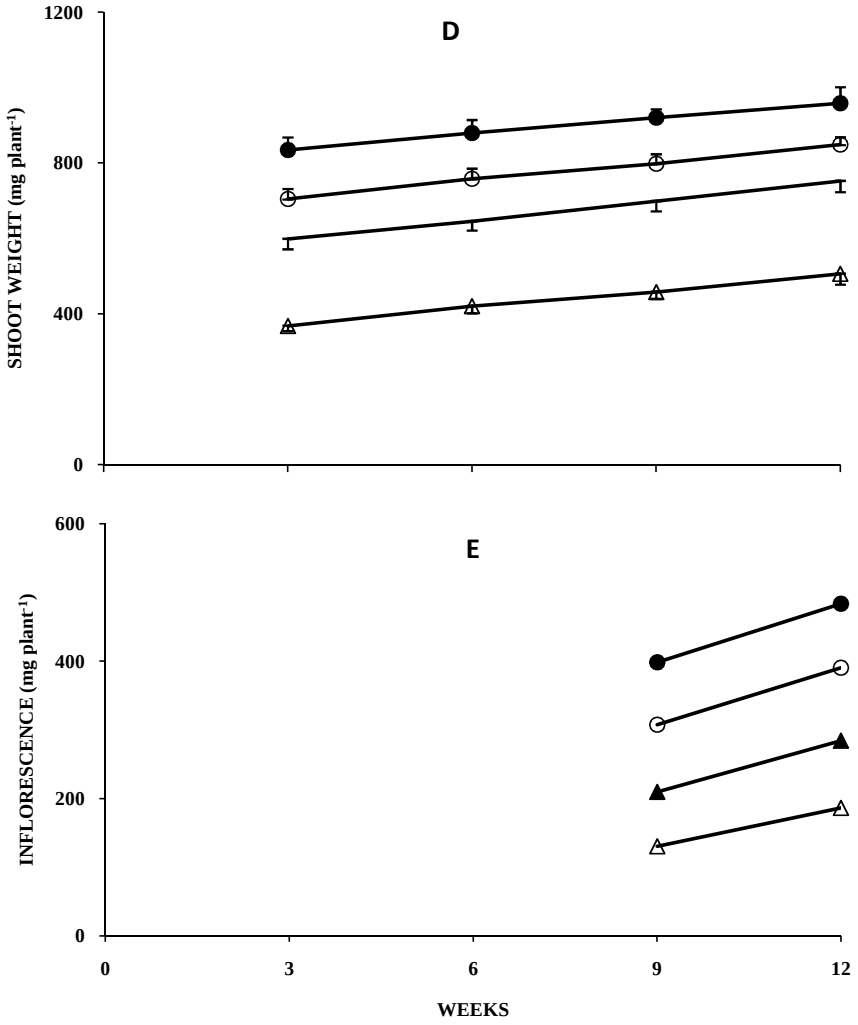

Fig. 14. Effect of soil salinity on dry weight of **D.**shoot and **E.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

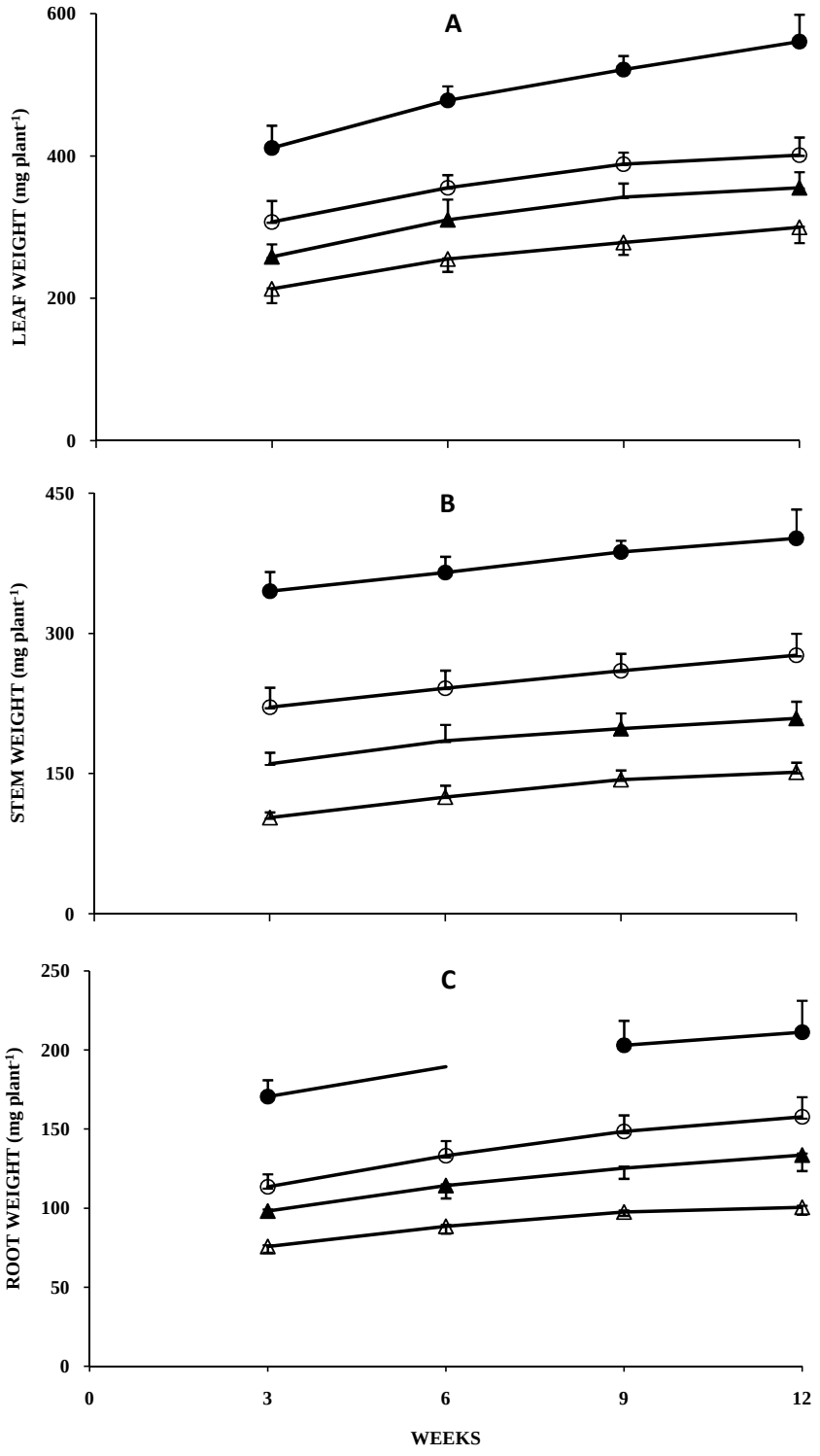

Fig. 15. Effect of soil salinity on dry weight of **A**.leaf, **B**.stem and **C**.root of *Pennisetum glaucum L.* variety **GHB 743** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

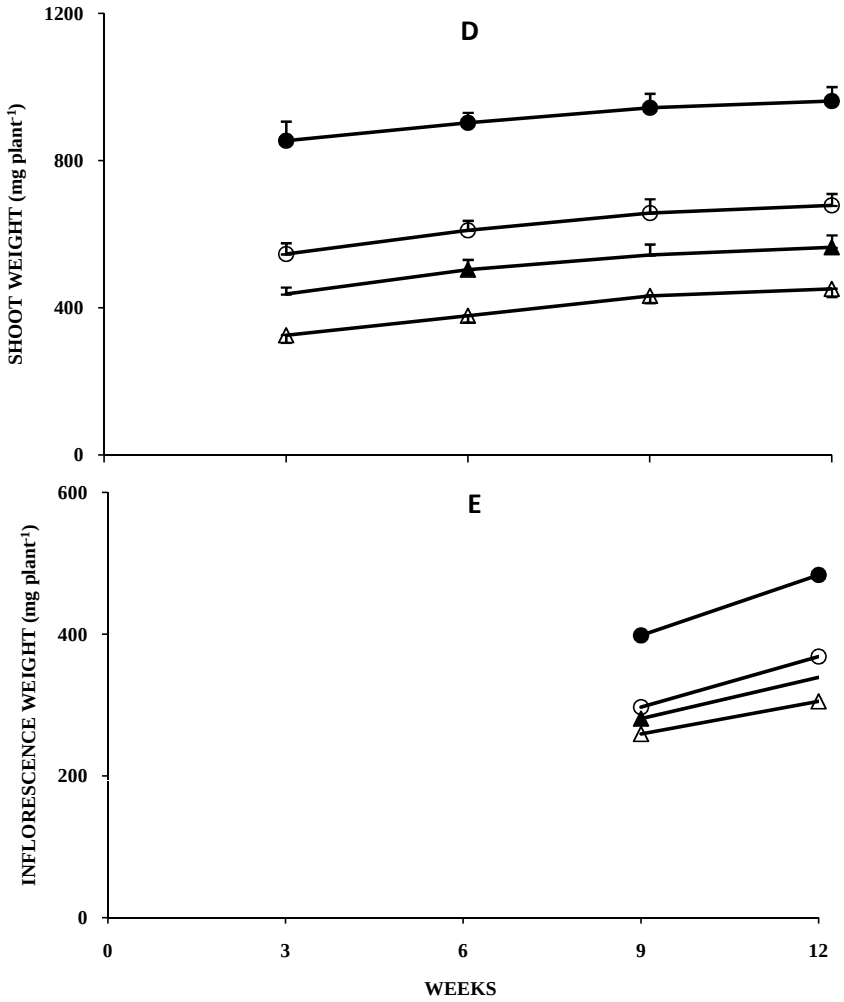

Fig. 15. Effect of soil salinity on dry weight of **D.**shoot and **E.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}.
Error bars represent SE.

Functional Growth Analysis (RGR, NAR and LAR)

The functional growth analysis approach was followed to assess the effect of increasing soil salinity on plant growth.

Variety GHB 538

Relative Growth Rate (RGR) of plants grown in saline soils decreased with increase in soil salinity (Fig. 16). There was maximum RGR at 9-week growth stage and minimum at 12-week growth stage for plants grown in both control and saline soils. There was a negative relationship between RGR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.65 – 0.01X$ ($r = -0.993$, $p<0.01$, $df = 3$)

Where Y is RGR ($g\ g^{-1}\ day^{-1}$) and X is soil salinity ($dS\ m^{-1}$).

The Net Assimilation Rate (NAR) of the control plants was consistently greater than that of salt-stressed plants (Fig. 16). At advanced age shoot tissues were metabolically least active therefore NAR decreased. There was a negative relationship between NAR at 12-week growth stage and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.988$, $p<0.01$, $df = 3$)

Where Y is NAR ($mg\ cm^{-2}\ day^{-1}$) and X is soil salinity ($dS\ m^{-1}$).

There was a positive relationship between RGR and NAR at 12-week growth stage for plants grown in control and saline conditions.

$Y = 0.55 + 6.80X$ ($r = 0.965$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is NAR (mg cm^{-2} day^{-1}).

Leaf Area Ratio (LAR) was maximum at 6-week growth stage and was followed by a decrease until 9-week growth period (Fig. 16). Thereafter LAR became constant till 12-week growth period. However, LAR for control plants was consistently greater than that for salt-stressed plants. There was a negative relationship between LAR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.953$, $p<0.05$, $df = 3$)

Where Y is LAR (cm^2 mg^{-1}) and X is soil salinity.

Variety GHB 558

Relative Growth Rate (RGR) of plants grown in saline soils decreased with increase in soil salinity (Fig. 17). There was maximum RGR at 9-week growth stage and minimum at 12-week growth stage for plants grown in both control and saline soils. There was a negative relationship between RGR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.72 – 0.01X$ ($r = -0.989$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is soil salinity (dS m^{-1}).

The Net Assimilation Rate (NAR) of the control plants was consistently greater than that of salt-stressed plants (Fig. 17). At advanced age shoot tissues were

metabolically least active therefore NAR decreased. There was a negative relationship between NAR at 12-week growth stage and soil salinity according to the following expression:

$Y = 0.01 – 0.0X$ ($r = -0.952$, $p<0.05$, $df = 3$)

Where Y is NAR (mg cm^{-2} day^{-1}) and X is soil salinity (dS m^{-1}).

There was a positive relationship between RGR and NAR at 12-week growth stage for plants grown in control and saline conditions.

$Y = 0.55 + 14.52X$ ($r = 0.971$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is NAR (mg cm^{-2} day^{-1}).

Leaf Area Ratio (LAR) was maximum at 6-week growth stage and was followed by a decrease until 9-week growth period (Fig. 17). Thereafter LAR became constant till 12-week growth period. However, LAR for control plants was consistently greater than that for salt-stressed plants. There was a negative relationship between LAR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.998$, $p<0.01$, $df = 3$)

Where Y is LAR (cm^2 mg^{-1}) and X is soil salinity (dS m^{-1}).

Variety GHB 577

Relative Growth Rate (RGR) of plants grown in saline soils decreased with increase in soil salinity (Fig. 18). There was maximum RGR at 9-week growth stage and minimum at 12-week growth stage for plants grown in both control and saline soils. There was a negative relationship between RGR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.68 – 0.01X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is soil salinity (dS m^{-1}).

The Net Assimilation Rate (NAR) of the control plants was consistently greater than that of salt-stressed plants (Fig. 18). At advanced age shoot tissues were metabolically least active therefore NAR decreased. There was a negative relationship between NAR at 12-week growth stage and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.948$, $p<0.05$, $df = 3$)

Where Y is NAR (mg cm^{-2} day^{-1}) and X is soil salinity (dS m^{-1}).

There was a positive relationship between RGR and NAR at 12-week growth stage for plants grown in control and saline conditions.

$Y = 0.51 + 23.70X$ ($r = 0.950$, $p<0.05$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is NAR (mg cm^{-2} day^{-1}).

Leaf Area Ratio (LAR) was maximum at 6-week growth stage and was followed by a decrease until 9-week growth period (Fig. 18). Thereafter LAR became constant till 12-week growth period. However, LAR for control plants was consistently

greater than that for salt-stressed plants. There was a negative relationship between LAR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.02 – 0.00X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Where Y is LAR ($cm^2\ mg^{-1}$) and X is soil salinity ($dS\ m^{-1}$).

Variety GHB 734

Relative Growth Rate (RGR) of plants grown in saline soils decreased with increase in soil salinity (Fig. 19). There was maximum RGR at 9-week growth stage and minimum at 12-week growth stage for plants grown in both control and saline soils. There was a negative relationship between RGR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.67 – 0.01X$ ($r = -0.997$, $p<0.01$, $df = 3$)

Where Y is RGR ($g\ g^{-1}\ day^{-1}$) and X is soil salinity ($dS\ m^{-1}$).

The Net Assimilation Rate (NAR) of the control plants was consistently greater than that of salt-stressed plants (Fig. 19). At advanced age shoot tissues were metabolically least active therefore NAR decreased. There was a negative relationship between NAR at 12-week growth stage and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.958$, $p<0.05$, $df = 3$)

Where Y is NAR ($mg\ cm^{-2}\ day^{-1}$) and X is soil salinity ($dS\ m^{-1}$).

There was a positive relationship between RGR and NAR at 12-week growth stage for plants grown in control and saline conditions.

$Y = 0.47 + 18.05X$ ($r = 0.976$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is NAR (mg cm^{-2} day^{-1}).

Leaf Area Ratio (LAR) was maximum at 6-week growth stage and was followed by a decrease until 9-week growth period (Fig. 19). Thereafter LAR became constant till 12-week growth period. However, LAR for control plants was consistently greater than that for salt-stressed plants. There was a negative relationship between LAR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.03 – 0.00X$ ($r = -0.997$, $p<0.01$, $df = 3$)

Where Y is LAR (cm^2 mg^{-1}) and X is soil salinity (dS m^{-1}).

Variety GHB 743

Increasing soil salinity caused reduction in Relative Growth Rate (RGR) of plants (Fig. 20). There was maximum RGR at 9-week growth stage and minimum at 12-week growth stage for plants grown in both control and saline soils. There was a negative relationship between RGR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.69 – 0.01X$ ($r = -0.987$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is soil salinity (dS m^{-1}).

Net Assimilation Rate (NAR) of the control plants was consistently greater than that of salt-stressed plants (Fig. 20). At advanced age shoot tissues were metabolically least active therefore NAR decreased. There was a negative relationship between NAR at 12-week growth stage and soil salinity according to the following expression:

$Y = 0.08 – 0.01X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Where Y is NAR (mg cm^{-2} day^{-1}) and X is soil salinity (dS m^{-1}).

There was a positive relationship between RGR and NAR at 12-week growth stage for plants grown in control and saline conditions.

$Y = 0.55 + 1.74X$ ($r = 0.982$, $p<0.01$, $df = 3$)

Where Y is RGR (g g^{-1} day^{-1}) and X is NAR (mg cm^{-2} day^{-1}).

Leaf Area Ratio (LAR) was maximum at 6-week growth stage and was followed by a decrease until 9-week growth period (Fig. 20). Thereafter LAR became constant till 12-week growth period. However, LAR for control plants was consistently greater than that for salt-stressed plants. There was a negative relationship between LAR at 12-week growth period and soil salinity according to the following expression:

$Y = 0.01 – 0.00X$ ($r = -0.995$, $p<0.01$, $df = 3$)

Where Y is LAR (cm^2 mg^{-1}) and X is soil salinity (dS m^{-1}).

Variation among varieties

In general, RGR was greater for varieties GHB 538, GHB 558 and GHB 577 than for varieties GHB 734 and GHB 743. As a result, former three varieties are better able to tolerate salt-stress than the latter two varieties.

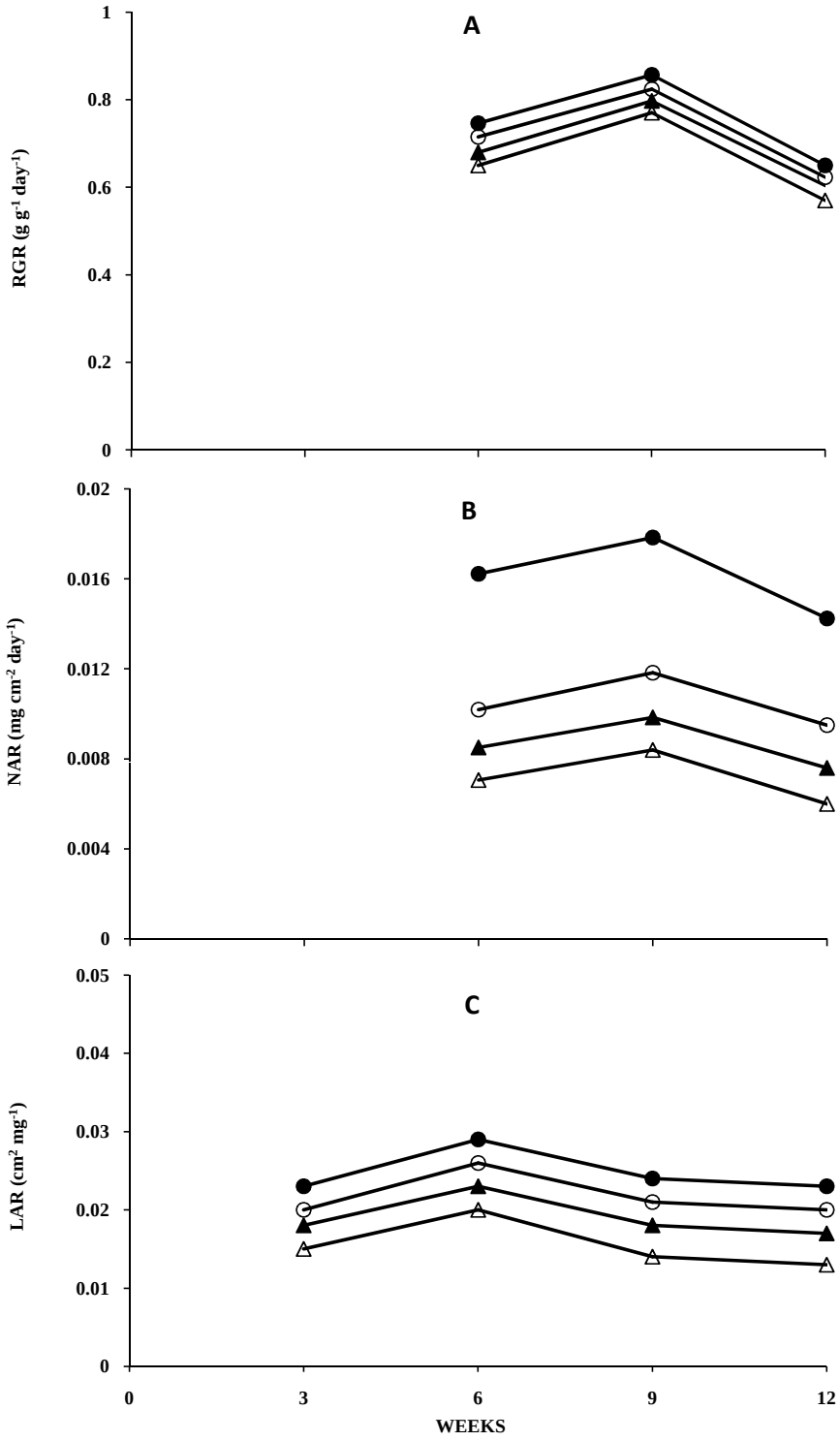

Fig. 16. Effect of soil salinity on **A**. RGR, **B**. NAR and **C**. LAR of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

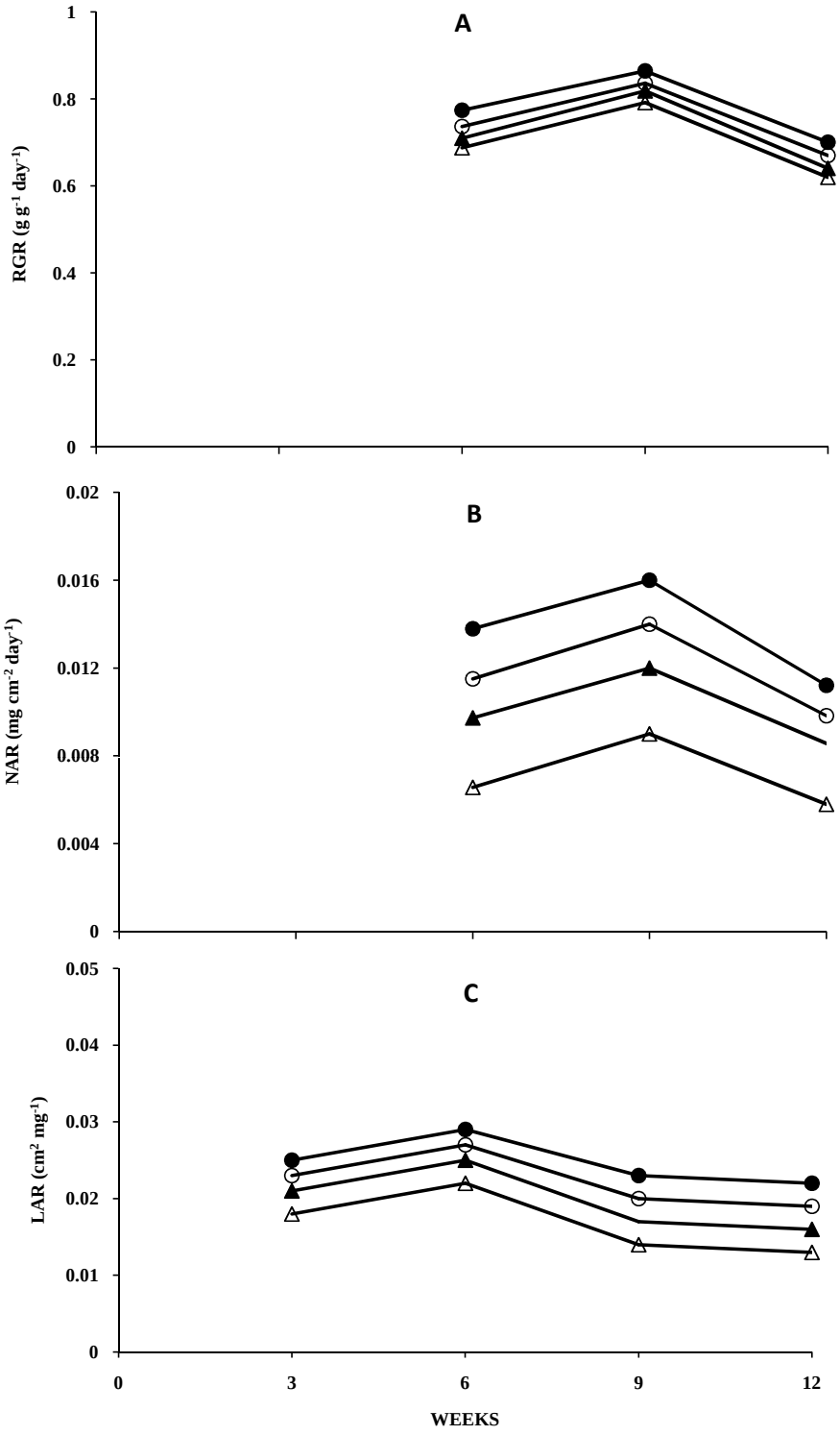

Fig. 17. Effect of soil salinity on **A**. RGR, **B**. NAR and **C**. LAR of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

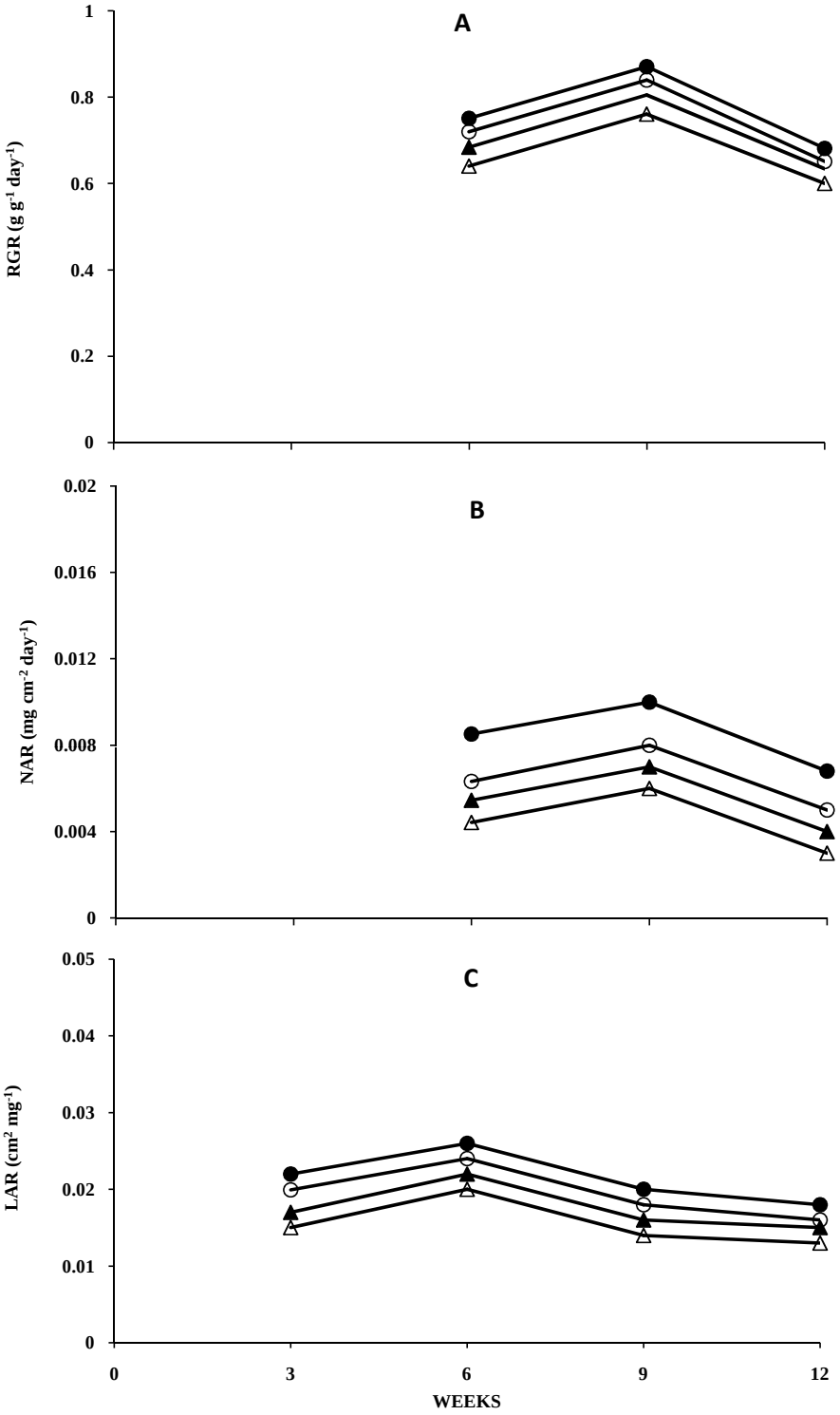

Fig. 18. Effect of soil salinity on **A**. RGR, **B**. NAR and **C**. LAR of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1} ; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

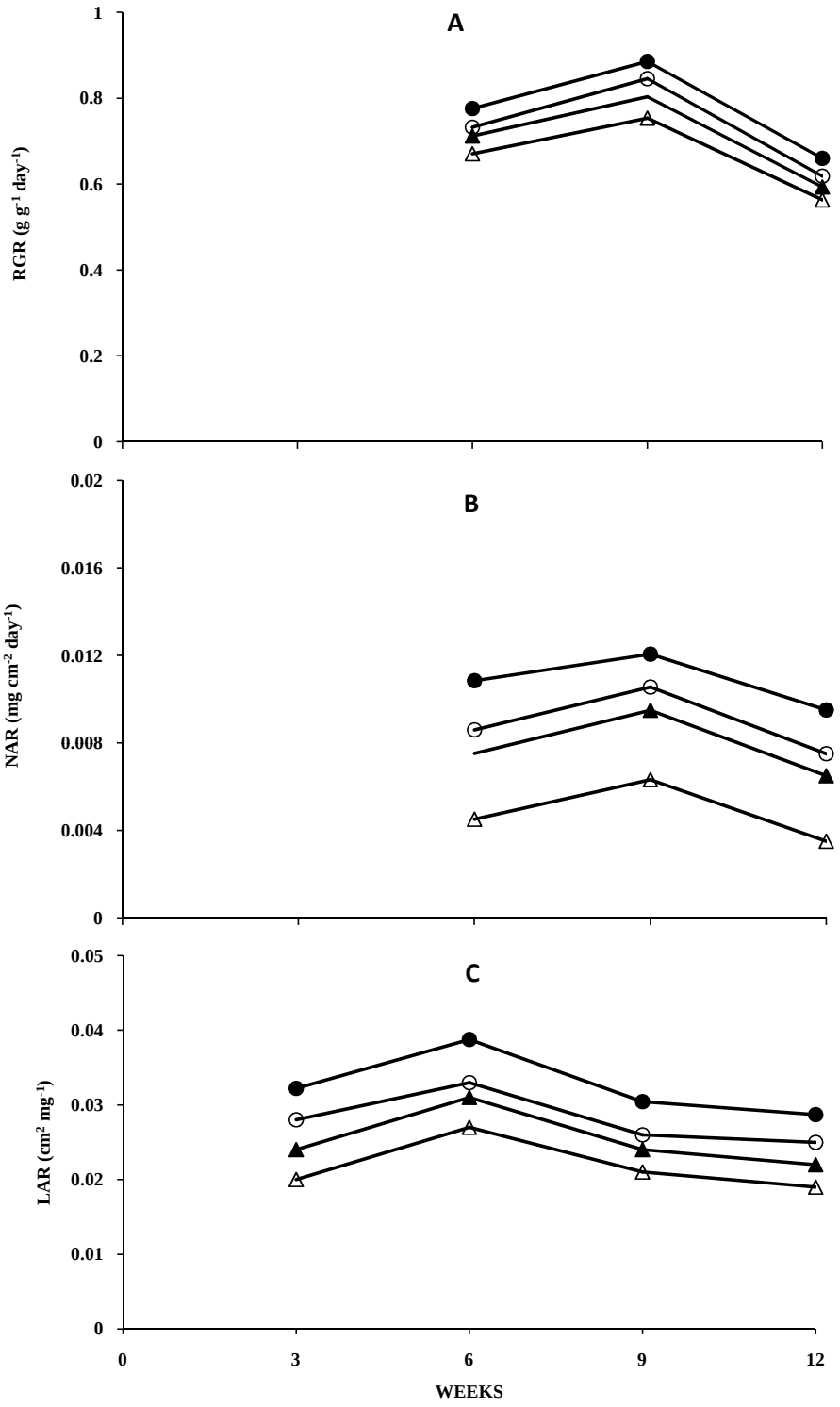

Fig. 19. Effect of soil salinity on **A**. RGR, **B**. NAR and **C**. LAR of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

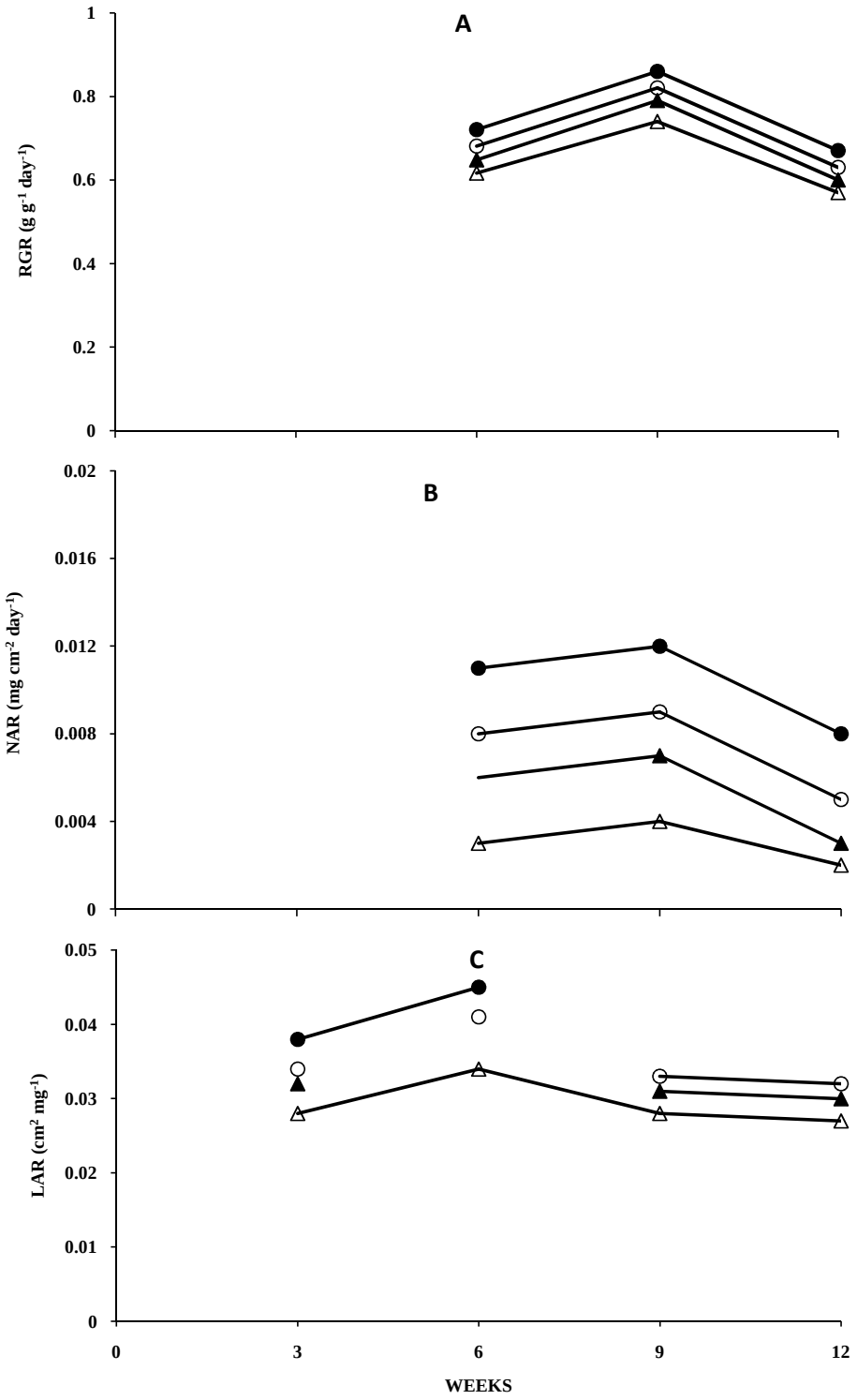

Fig. 20. Effect of soil salinity on **A**. RGR, **B**. NAR and **C**. LAR of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Effect of Salinity on Water Status, Proline Content, Carbohydrates, Proteins and Lipids in Tissues

Water content of tissues

Values of water content of tissues for control and salt-stressed plants were averaged separately on the data of two years experiment and results are presented below:

Variety GHB 538

Water content (g g^{-1}dry weight) significantly decreased for leaves ($p<0.01$), stems ($p<0.01$) and roots ($p<0.05$) significantly decreased over time for control as well as salt-stressed plants (Fig. 21). Further, water content in tissues of control plants was consistently greater than that in tissues of salt-stressed plants. Salt stress caused significant reduction in water content of leaves ($p<0.01$), inflorescences, stems and roots ($p<0.05$). Water content was maximum in leaves and inflorescences, whereas it was minimum in stems and roots of control as well as salt-stressed plants. There was a negative relationship between water content of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = 5.88 – 0.37X$ ($r = -0.441$, $p<0.01$, $df = 71$)

Stem: $Y = 4.38 – 0.22X$ ($r = -0.275$, $p<0.01$, $df = 71$)

Root: $Y = 4.69 – 0.28X$ ($r = -0.336$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 5.74 – 0.29X$ ($r = - 0.351$, $p<0.01$, $df = 71$)

Where Y is water content (g g^{-1} dry weight) of tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 558

Water content (g g^{-1}dry weight) of leaves, stems and roots of control and salt-stressed plants significantly decreased ($p<0.05$) as the age advanced (Fig 22). Moreover, water content in tissues of control plants was consistently greater than that in tissues of salt-stressed plants. Salt stress caused significant reduction ($p<0.05$) in water content of tissues. Water content was maximum in leaves and inflorescences, whereas it was minimum in stems and roots of both control and salt-stressed plants. There was a negative relationship between water content of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = 7.02 – 0.41X$ ($r = -0.359$, $p<0.01$, $df = 71$)

Stem: $Y = 4.62 – 0.23X$ ($r = -0.324$, $p<0.01$, $df = 71$)

Root: $Y = 4.61 – 0.22X$ ($r = -0.243$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 6.67 – 0.26X$ ($r = - 0.166$, $p<0.05$, $df = 71$)

Where Y is water content (g g^{-1} dry weight) of tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 577

Water content (g g^{-1}dry weight) of leaves, stems and roots of control and salt-stressed plants significantly decreased ($p<0.05$) as the age increased (Fig. 23). Further, water content in tissues of control plants was consistently greater than that in tissues of salt-stressed plants. Salt stress caused significant reduction ($p<0.05$) in water content of tissues. Water content was maximum in leaves and inflorescences, whereas it was minimum in stems and roots of both control and salt-stressed plants. There was a negative relationship between water content of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = 5.74 – 0.30X$ ($r = -0.298$, $p<0.01$, $df = 71$)

Stem: $Y = 4.46 – 0.19X$ ($r = -0.177$, $p<0.05$, $df = 71$)

Root: $Y = 4.47 – 0.21X$ ($r = -0.211$, $p<0.05$, $df = 71$)

Inflorescence: $Y = 5.20 – 0.26X$ ($r = - 0.219$, $p<0.05$, $df = 71$)

Where Y is water content (g g^{-1} dry weight) of tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 734

Water content (g g^{-1}dry weight) of leaves, stems and roots of control and salt stressed plants significantly decreased ($p<0.05$) as the age advanced (Fig. 24). Moreover, water content in tissues of control plants was greater than that in tissues of salt-stressed plants. Salt stress caused significant reduction in water content of leaves ($p<0.05$), inflorescences ($p<0.05$), stems and roots ($p<0.01$). Water content

was maximum in leaves and inflorescences, whereas it was minimum in roots of both control and salt-stressed plants. There was a negative relationship between water content of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = 3.94 – 0.26X$ ($r = -0.294$, $p<0.01$, $df = 71$)

Stem: $Y = 4.41 – 0.32X$ ($r = -0.432$, $p<0.01$, $df = 71$)

Root: $Y = 3.75 – 0.25X$ ($r = -0.402$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 3.64 – 0.18X$ ($r = - 0.211$, $p<0.05$, $df = 71$)

Where Y is water content (g g^{-1} dry weight) of tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 743

Water content (g g^{-1}dry weight) significantly decreased for leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.05$) of control and salt-stressed plants as the age advanced (Fig. 25). Moreover, water content in tissues of control plants was consistently greater than that in tissues of salt-stressed plants. Salt stress caused significant reduction in water content of leaves ($p<0.01$), inflorescences ($p<0.05$), stems and roots ($p<0.01$). Water content was maximum in leaves and inflorescences, whereas it was minimum in stems and roots of both control and salt-stressed plants. There was a negative relationship between water content of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = 4.26 – 0.23X$ ($r = -0.359$, $p<0.01$, $df = 71$)

Stem: $Y = 3.76 – 0.24X$ ($r = -0.365$, $p<0.01$, $df = 71$)

Root: $Y = 4.35 – 0.25X$ ($r = -0.338$, $p<0.01$, $df = 71$)

Inflorescence: $Y = 4.16 – 0.27X$ ($r = - 0.335$, $p<0.01$, $df = 71$)

Where Y is water content (g g^{-1} dry weight) of tissues and X is salt concentration in soil (dS m^{-1}).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for water content in tissues (leaves, stems, roots and inflorescences) in response to salinity. In general, concentration of water content was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

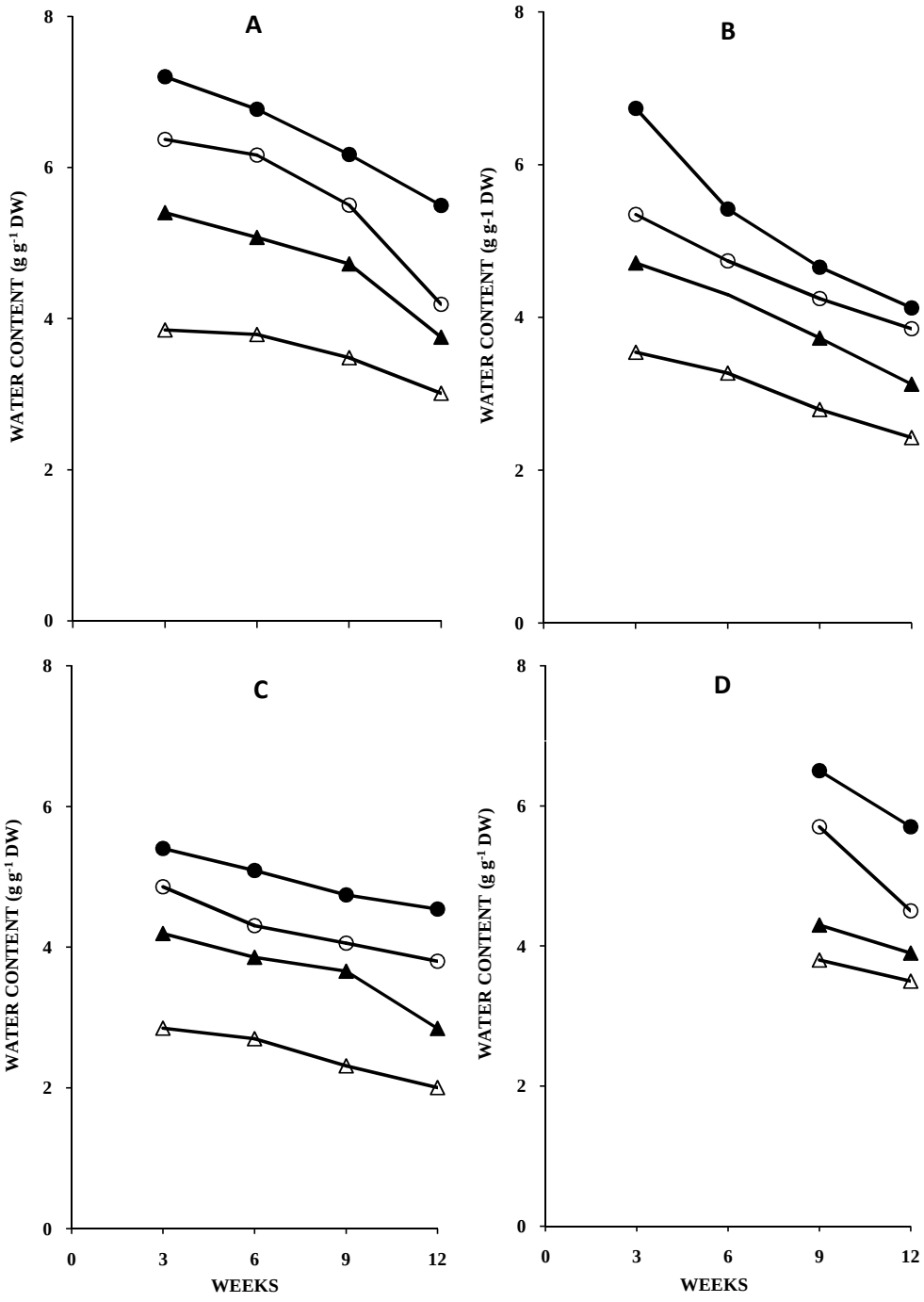

Fig. 21. Effect of soil salinity on water content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

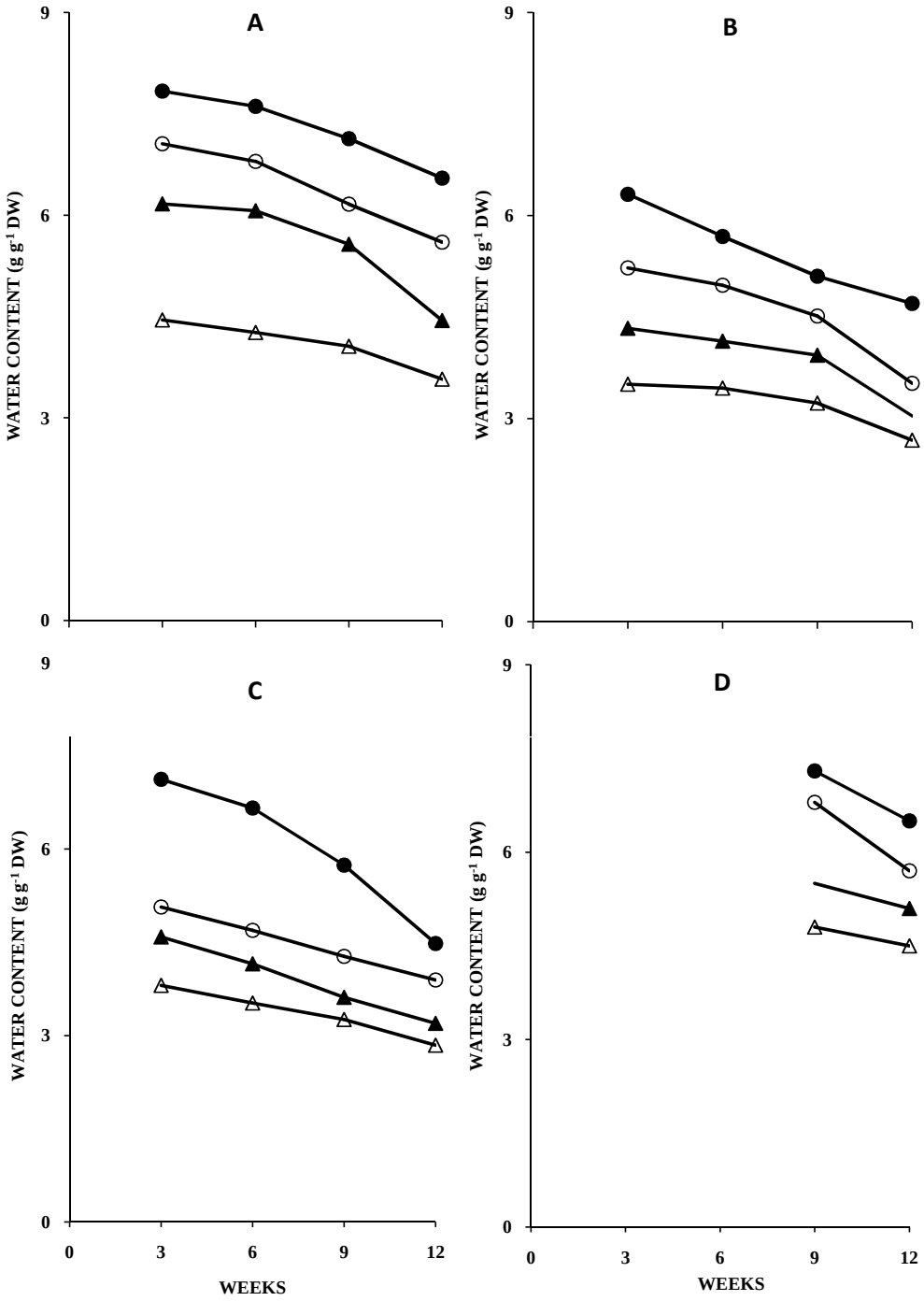

Fig. 22. Effect of soil salinity on water content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

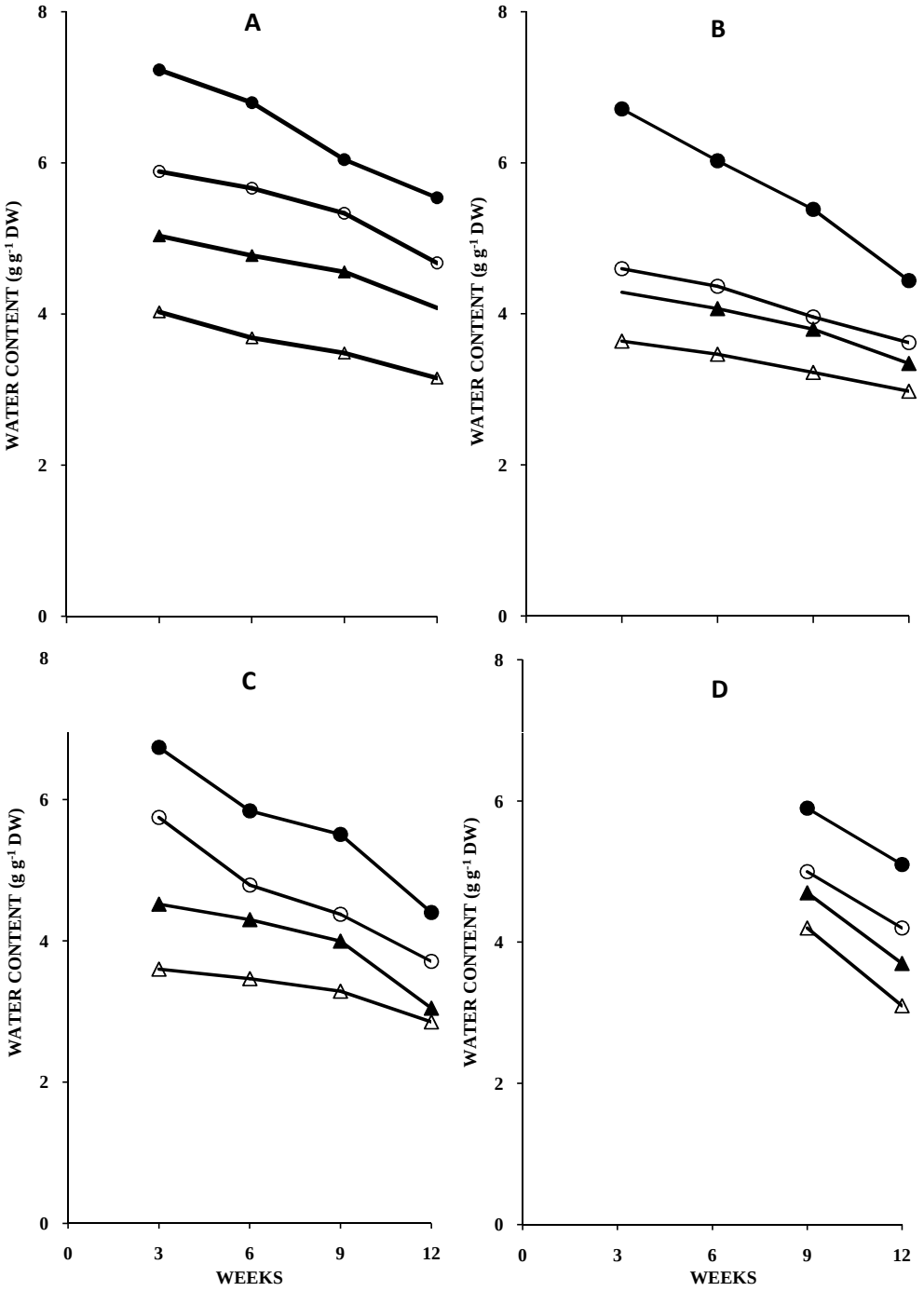

Fig. 23. Effect of soil salinity on water content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

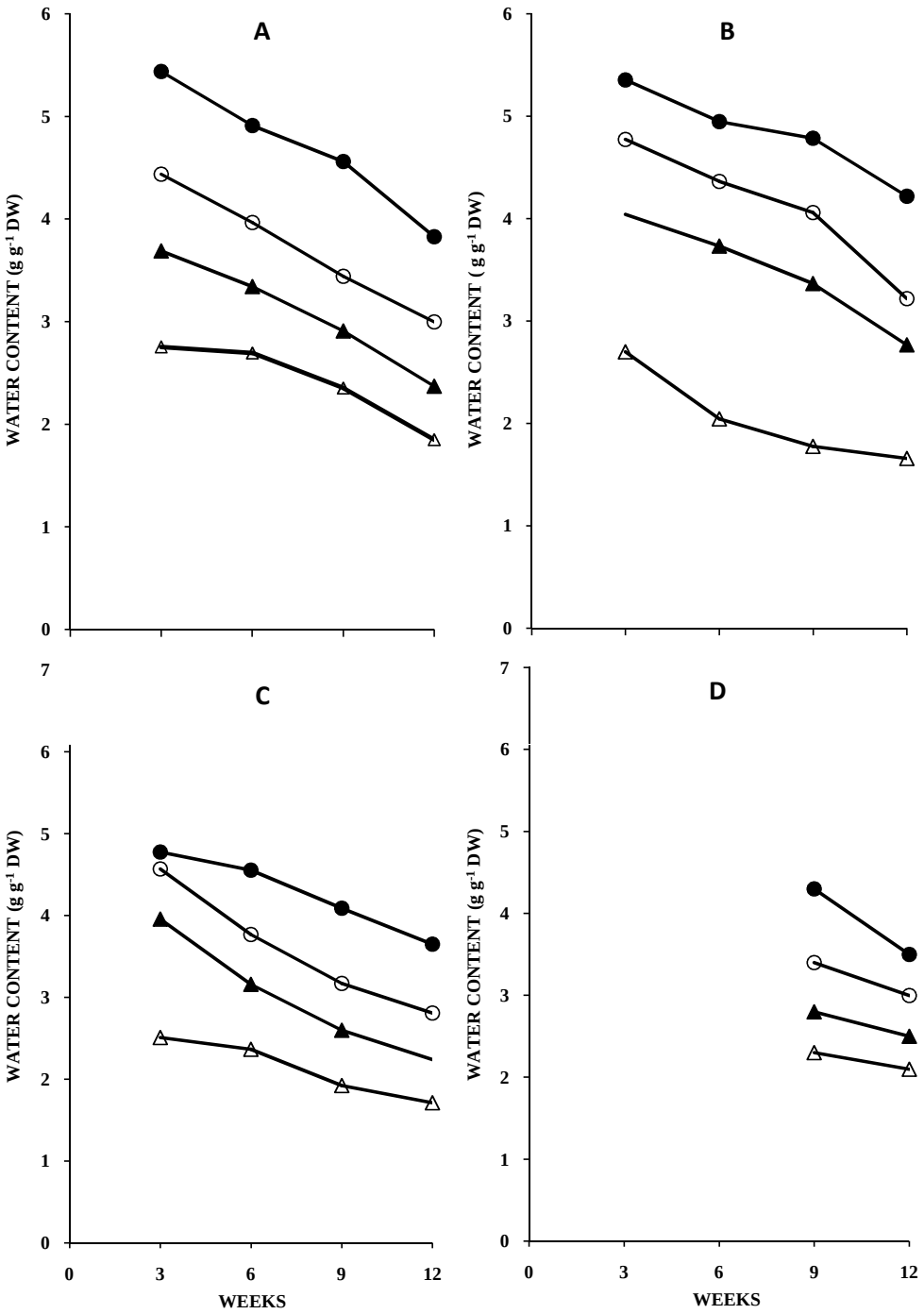

Fig. 24. Effect of soil salinity on water content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

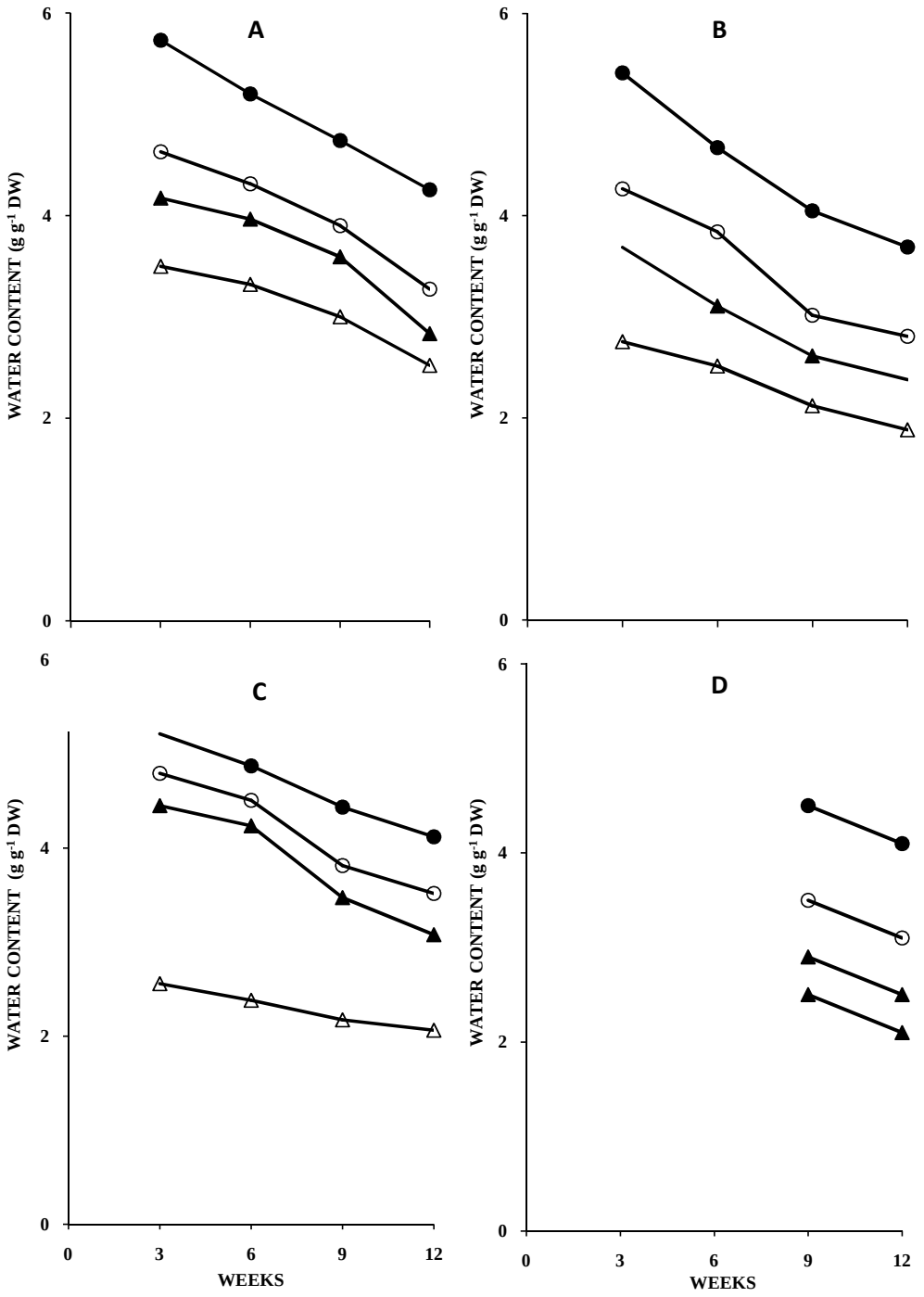

Fig. 25. Effect of soil salinity on water content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Water potential of tissues

Water potential of tissues for control and salt-stressed plants was measured only during the second year experiment and results are presented below:

Variety GHB 538

Water potential of leaves, stems, roots and inflorescences of control and salt-stressed plants became significantly negative ($p<0.01$) as the age increased (Fig. 26). Moreover, water potential in tissues of control plants was less negative than that in tissues of salt-stressed plants. Salt stress significantly ($p<0.01$) lowered the water potential of tissues. Among tissues, water potential was least negative in leaves and inflorescence, whereas it was most negative in roots and stems for control as well as salt-stressed plants. There was a significant negative relationship between water potential of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = -5.79 - 0.37X$ ($r = -0.998$, $p<0.01$, $df = 11$)

Stem: $Y = -6.01 - 0.39X$ ($r = -0.987$, $p<0.01$, $df = 11$)

Root: $Y = -6.63 - 0.37X$ ($r = -0.938$, $p<0.01$, $df = 11$)

Inflorescence: $Y = -5.32 – 0.48X$ ($r = - 0.944$, $p<0.01$, $df = 11$)

Where Y is water potential (-MPa) of tissues and X is salt concentration in soil (dS m^{-1}).

A significant positive relationship was obtained between water content and water potential of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = -11.59 + 0.98X$ ($r = 0.982$, $p<0.01$, $df = 3$)

Stem: $Y = -13.26 + 1.61X$ ($r = 0.939$, $p<0.01$, $df = 3$)

Root: $Y = -12.66 + 1.27X$ ($r = 0.932$, $p<0.01$, $df = 3$)

Inflorescence: $Y = -14.70 + 1.63X$ ($r = 0.982$, $p<0.01$, $df = 3$)

Where Y is water potential (-MPa) of tissues and X is water content of tissues (g g^{-1} dry weight).

Variety GHB 558

Water potential of leaves, stems, roots and inflorescences of control and salt-stressed plants became significantly negative ($p<0.01$) as the age increased (Fig. 27). Moreover, water potential in tissues of control plants was less negative than that in tissues of salt-stressed plants. Salt stress caused a significant reduction ($p<0.01$) in water potential of tissues. Among the tissues, water potential was least negative in leaves and inflorescences, whereas it was most negative in roots for both control as well as salt-stressed plants. There was a significant negative relationship between water potential of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = -6.14 - 0.31X$ ($r = -0.968$, $p<0.01$, $df = 11$)

Stem: $Y = -6.22 - 0.33X$ ($r = -0.990$, $p<0.01$, $df = 11$)

Root: Y = -7.25 - 0.26X (r = -0.869, $p<0.01$, df = 11)

Inflorescence: Y = -5.85 – 0.45X (r = - 0.918, $p<0.01$, df = 11)

Where Y is water potential (-MPa) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant positive relationship between water content and water potential of tissues at 12-week growth stage according to the following expressions:

Leaf: Y = -11.36 + 0.75X (r = 0.996, $p<0.01$, df = 3)

Stem: Y = -12.34 +1.29X (r = 0.947, $p<0.01$, df = 3)

Root: Y = -12.63 + 1.17X (r = 0.905, $p<0.01$, df = 3)

Inflorescence: Y = -17.31 + 1.72X (r = 0.994, $p<0.01$, df = 3)

Where Y is water potential (-MPa) of tissues and X is water content of tissues (g g^{-1} dry weight).

Variety GHB 577

Water potential of leaves, stems, roots and inflorescences of control and salt-stressed plants became significantly negative ($p<0.01$) as the age advanced (Fig. 28). Moreover, water potential in tissues of control plants was less negative than that in tissues of salt-stressed plants. Salt stress significantly ($p<0.01$) lowered the water potential of tissues. Among the tissues, water potential was least negative in leaves and inflorescences, whereas it was most negative in roots for control as well as salt-stressed plants. There was a significant negative relationship between water

potential of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = -7.40 - 0.20X$ ($r = -0.946$, $p<0.01$, $df = 11$)

Stem: $Y = -7.67 - 0.28X$ ($r = -0.966$, $p<0.01$, $df = 11$)

Root: $Y = -7.44 - 0.34X$ ($r = -0.973$, $p<0.01$, $df = 11$)

Inflorescence: $Y = -7.56 – 0.22X$ ($r = - 0.924$, $p<0.01$, $df = 11$)

Where Y is water potential (-MPa) of tissues and X is salt concentration in soil (dS m^{-1}).

A significant positive relationship was obtained between water content and water potential of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = -11.22 + 0.67X$ ($r = 0.995$, $p<0.01$, $df = 3$)

Stem: $Y = -15.32 + 1.74X$ ($r = 0.973$, $p<0.01$, $df = 3$)

Root: $Y = -14.50 + 1.58X$ ($r = 0.999$, $p<0.01$, $df = 3$)

Inflorescence: $Y = -12.01 + 0.86X$ ($r = 0.993$, $p<0.01$, $df = 3$)

Where Y is water potential (-MPa) of tissues and X is water content of tissues (g g^{-1} dry weight).

Variety GHB 734

Water potential of leaves, stems, roots and inflorescences of control and salt-stressed plants became significantly negative ($p<0.01$) as the age advanced (Fig. 29). Moreover, water potential in tissues of control plants was less negative than that in tissues of salt-stressed plants. Salt stress caused a significant reduction ($p<0.01$) in water potential of tissues. Among the tissues, water potential was least negative in leaves and inflorescences, whereas it was most negative in roots and stems for both control as well as salt-stressed plants. There was a significant negative relationship between water potential of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = -5.09 - 0.41X$ ($r = -0.982$, $p<0.01$, $df = 11$)

Stem: $Y = -5.48 - 0.45X$ ($r = -0.985$, $p<0.01$, $df = 11$)

Root: $Y = -6.68 - 0.41X$ ($r = -0.976$, $p<0.01$, $df = 11$)

Inflorescence: $Y = -5.31 – 0.39X$ ($r = - 0.966$, $p<0.01$, $df = 11$)

Where Y is water potential (-MPa) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant positive relationship between water content and water potential of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = -11.32 + 1.58X$ ($r = 0.989$, $p<0.01$, $df = 3$)

Stem: $Y = -11.67 +1.39X$ ($r = 0.991$, $p<0.01$, $df = 3$)

Root: $Y = -12.68 + 1.59X$ ($r = 0.980$, $p<0.01$, $df = 3$)

Inflorescence: $Y = -13.29 + 2.19X$ ($r = 0.994$, $p<0.01$, $df = 3$)

Where Y is water potential (-MPa) of tissues and X is water content of tissues (g g^{-1} dry weight).

Variety GHB 743

Water potential of leaves, stems, roots and inflorescences of control and salt-stressed plants became significantly negative ($p<0.01$) as the age advanced (Fig. 30). Moreover, water potential in tissues of control plants was less negative than that in tissues of salt-stressed plants. Salt stress caused a significant reduction ($p<0.01$) in water potential of tissues. Among the tissues, water potential was less negative in leaves and inflorescences, whereas it was more negative in roots for both control as well as salt-stressed plants. There was a significant negative relationship between water potential of tissues at 12-week growth period and salt concentration according to the following expressions:

Leaf: $Y = -5.29 - 0.43X$ ($r = -0.995$, $p<0.01$, $df = 11$)

Stem: $Y = -5.48 - 0.41X$ ($r = -0.975$, $p<0.01$, $df = 11$)

Root: $Y = -6.16 - 0.33X$ ($r = -0.988$, $p<0.01$, $df = 11$)

Inflorescence: $Y = -5.39 – 0.48X$ ($r = - 0.972$, $p<0.01$, $df = 11$)

Where Y is water potential (-MPa) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant positive relationship between water content and water potential of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = -13.19 + 1.85X$ ($r = 0.996$, $p<0.01$, $df = 3$)

Stem: $Y = -11.99 + 1.73X$ ($r = 0.974$, $p<0.01$, $df = 3$)

Root: $Y = -11.49 + 1.21X$ ($r = 0.981$, $p<0.01$, $df = 3$)

Inflorescence: $Y = -12.81 + 1.78X$ ($r = 0.999$, $p<0.01$, $df = 3$)

Where Y is water potential (-MPa) of tissues and X is water content of tissues (g g^{-1} dry weight).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in water potential of tissues (leaves, stems, roots and inflorescences) in response to salinity.

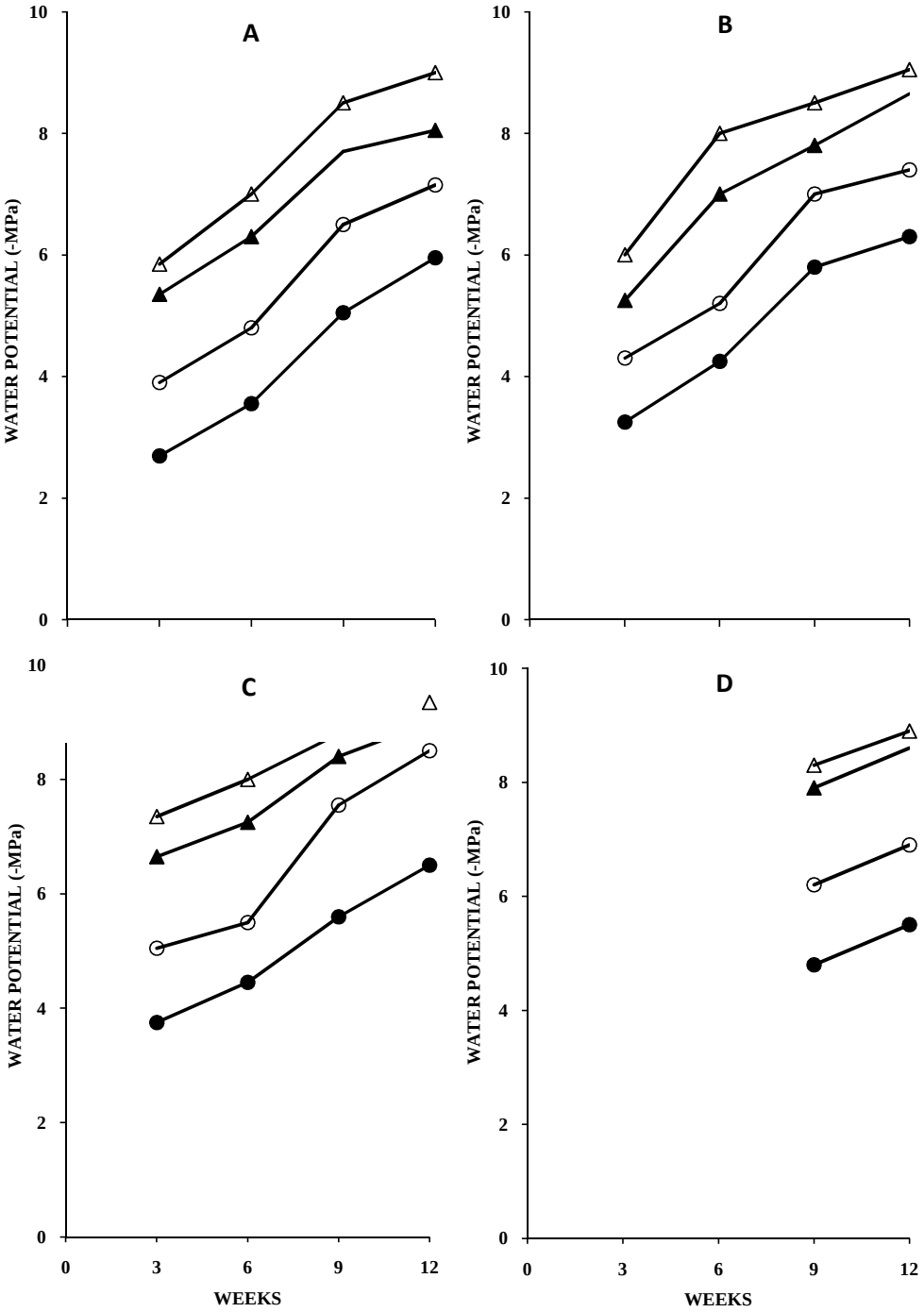

Fig. 26. Effect of soil salinity on water potential of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

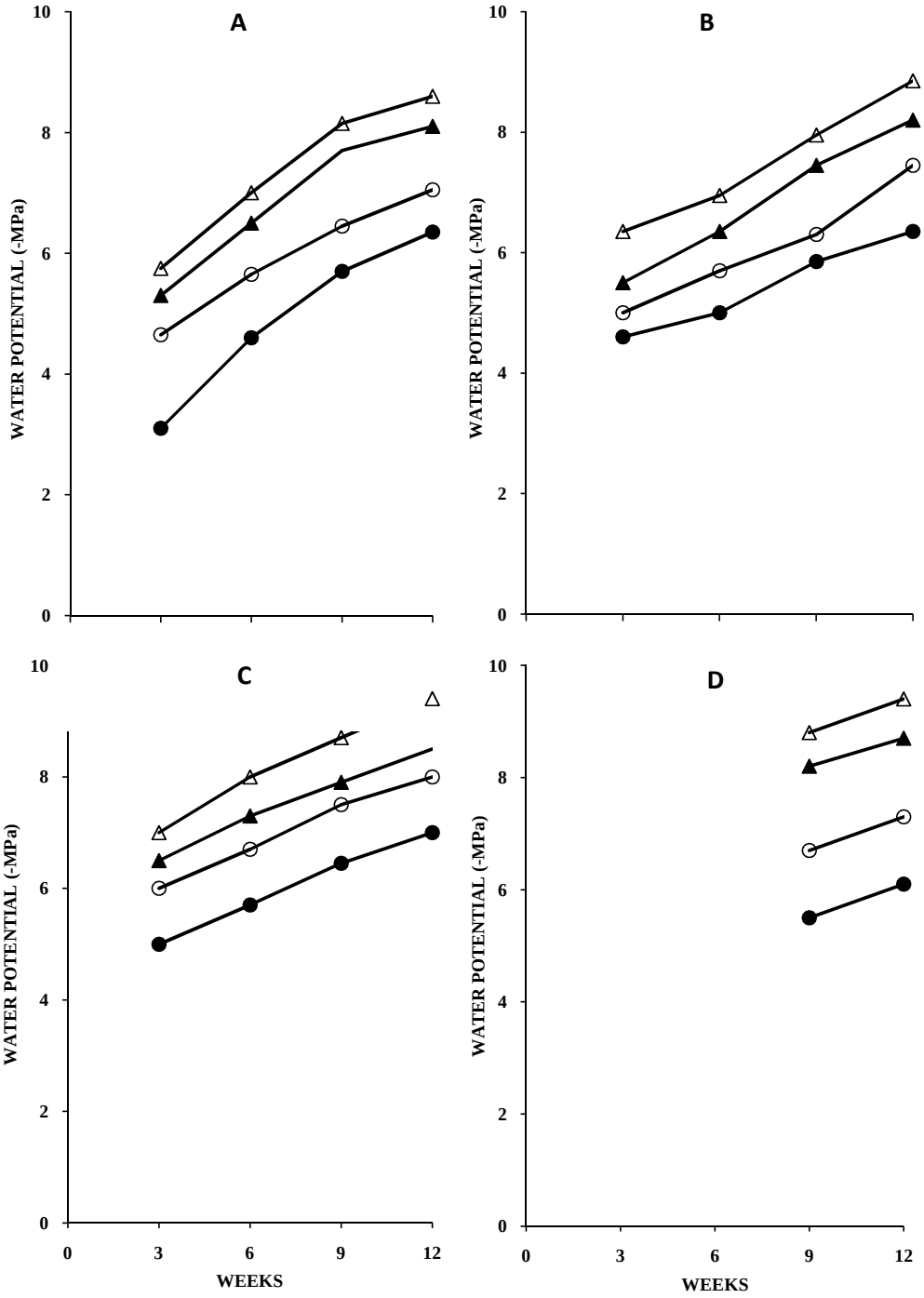

Fig. 27. Effect of soil salinity on water potential of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

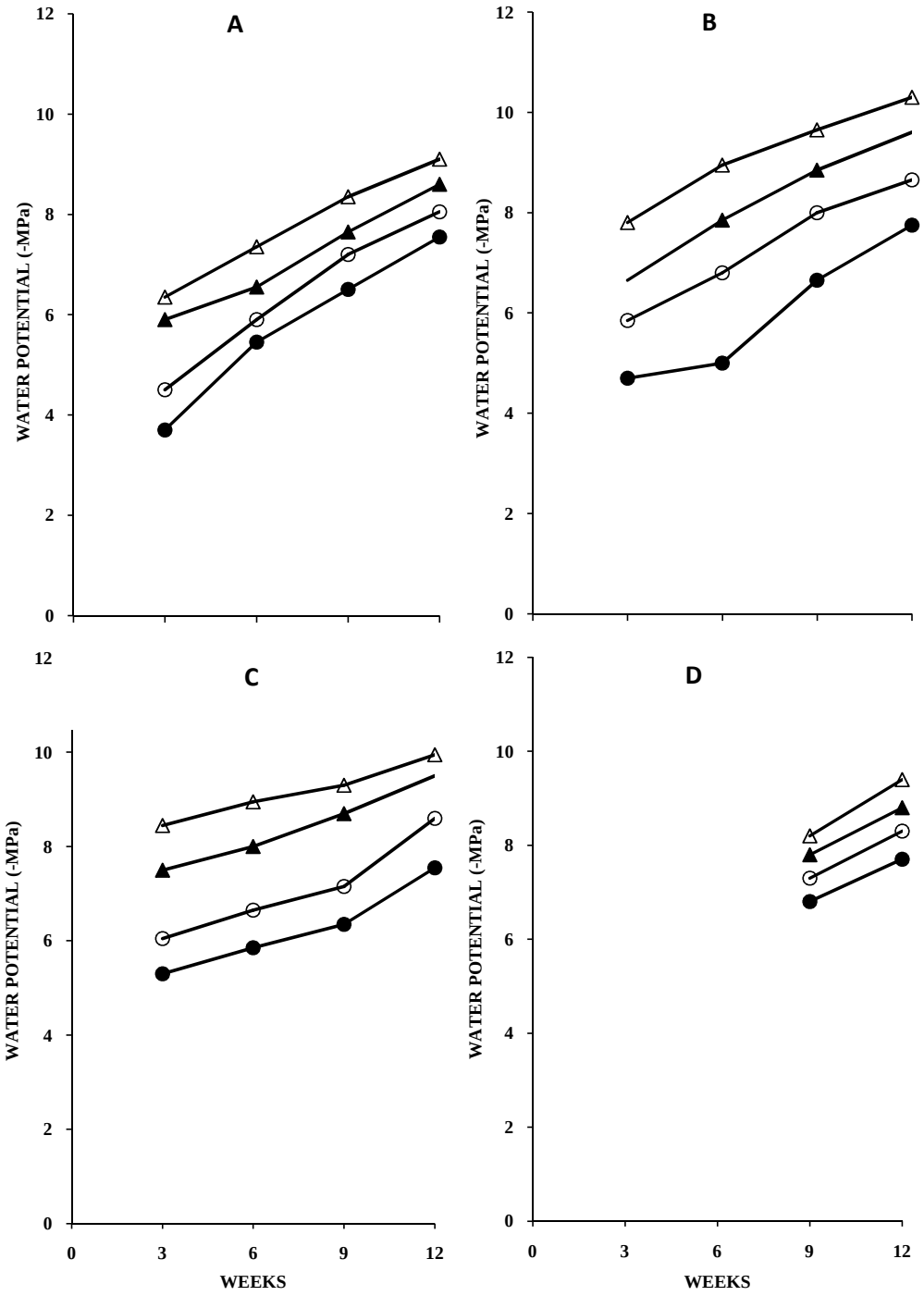

Fig. 28. Effect of soil salinity on water potential of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

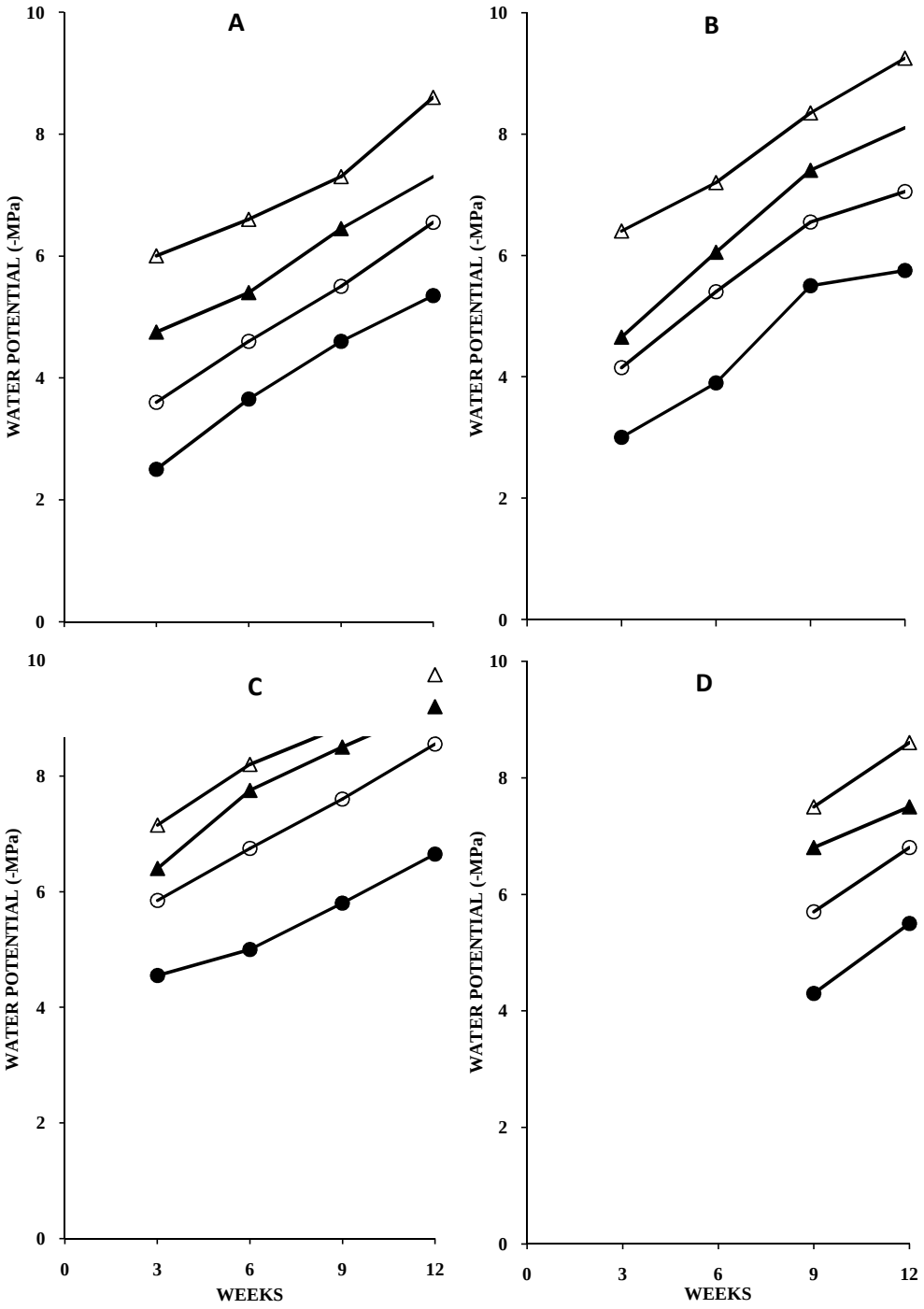

Fig. 29. Effect of soil salinity on water potential of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

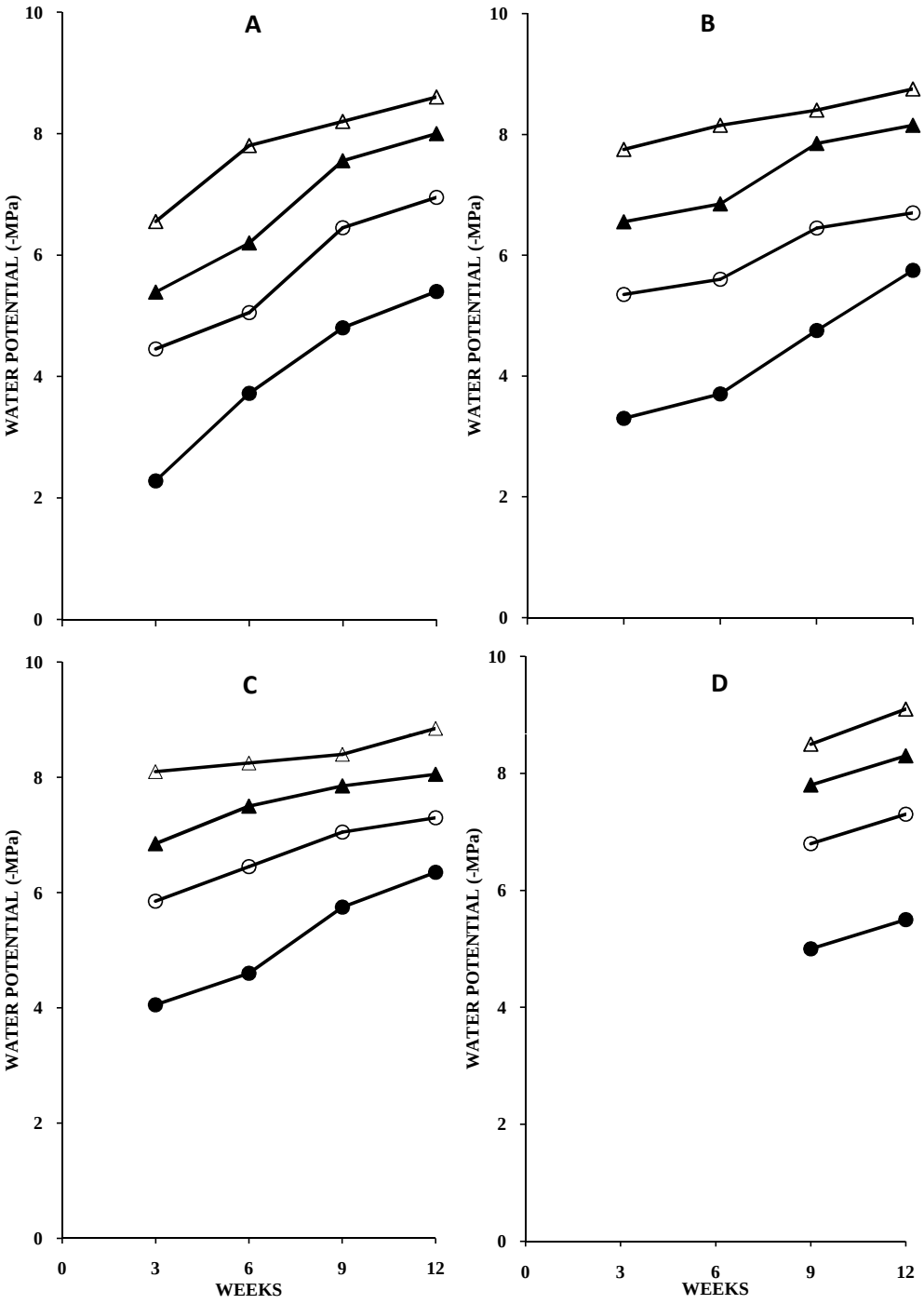

Fig. 30. Effect of soil salinity on water potential of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Proline content of tissues

Proline content of tissues for control and salt-stressed plants was determined only during the second year experiment and results are given below:

Variety GHB 538

As the age increased for control and salt-stressed plants, proline content (μmol g^{-1} FW) of leaves, stems and roots significantly increased ($p<0.01$) (Fig. 31). Proline content in tissues significantly increased ($p<0.01$) in response to increase in soil salinity. Moreover, proline content in tissues of salt-stressed plants was consistently greater than that in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants proline content was maximum in leaves and minimum in roots at all the growth stages. A significant positive relationship was obtained between proline content of tissues at 12-week growth stage and salt concentration in soil according to the following expressions:

Leaf: $Y = 13.22 + 0.42X$ ($r = 0.959$, $p<0.01$, $df = 11$)

Stem: $Y = 11.52 + 0.41X$ ($r = 0.956$, $p<0.01$, $df = 11$)

Root: $Y = 9.22 + 0.38X$ ($r = 0.953$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 9.17 + 0.33X$ ($r = 0.963$, $p<0.01$, $df = 11$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant negative relationship between water content and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 20.74 – 1.75X$ ($r = -0.965$, $p<0.01$, $df = 3$)

Stem: $Y = 18.05 – 1.74X$ ($r = -0.996$, $p<0.01$, $df = 3$)

Root: $Y = 15.51 – 1.43X$ ($r = -0.979$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 14.30 – 1.23X$ ($r = -0.974$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water content of tissues (g g^{-1} dry weight).

A significant negative relationship was obtained between water potential and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 6.70 – 1.12X$ ($r = -0.993$, $p<0.01$, $df = 3$)

Stem: $Y = 5.47 – 1.01X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Root: $Y = 3.38 – 0.91X$ ($r = -0.905$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 5.72 – 0.66X$ ($r = -0.954$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water potential of tissues (-MPa).

Variety GHB 558

Proline content (μmol g^{-1} FW) of leaves, stems and roots significantly increased ($p<0.01$) as the age of control and salt-stressed plants advanced (Fig. 32). Proline content in tissues significantly increased ($p<0.01$) in response to increase in soil salinity. Moreover, proline content in tissues of salt-stressed plants was consistently greater than that in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants proline content was maximum in leaves and minimum in roots at all the growth stages. There was a significant positive relationship between proline content of tissues at 12-week growth stage and salt concentration in soil according to the following expressions:

Leaf: $Y = 14.70 + 0.52X$ ($r = 0.958$, $p<0.01$, $df = 11$)

Stem: $Y = 12.66 + 0.49X$ ($r = 0.952$, $p<0.01$, $df = 11$)

Root: $Y = 10.73 + 0.46X$ ($r = 0.977$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 10.46 + 0.43X$ ($r = 0.965$, $p<0.01$, $df = 11$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant negative relationship between water content and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 24.24 – 2.22X$ ($r = -0.976$, $p<0.01$, $df = 3$)

Stem: $Y = 20.52 – 2.09X$ ($r = -0.982$, $p<0.01$, $df = 3$)

Root: $Y = 18.21 – 1.69X$ ($r = -0.980$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 17.16 – 1.60X$ ($r = -0.974$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water content of tissues (g g^{-1} dry weight).

A significant negative relationship was obtained between water potential and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.43 – 1.68X$ ($r = -0.993$, $p<0.01$, $df = 3$)

Stem: $Y = 3.28 – 1.50X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Root: $Y = 0.46 – 1.47X$ ($r = -0.927$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 4.81 – 0.97X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water potential of tissues (-MPa).

Variety GHB 577

Proline content (μmol g^{-1} FW) of leaves, stems and roots significantly increased ($p<0.01$) with increase of age of control and salt-stressed plants (Fig. 33). Proline content in tissues significantly increased ($p<0.01$) in response to increase in soil salinity. Moreover, proline content in tissues of salt-stressed plants was consistently greater than that in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants proline content was maximum in leaves and minimum in roots at all the growth stages. A significant positive relationship was

obtained between proline content of tissues at 12-week growth stage and salt concentration in soil according to the following expressions:

Leaf: $Y = 14.13 + 0.42X$ ($r = 0.978$, $p<0.01$, $df = 11$)

Stem: $Y = 12.77 + 0.37X$ ($r = 0.889$, $p<0.01$, $df = 11$)

Root: $Y = 11.01 + 0.38X$ ($r = 0.948$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 10.73 + 0.39X$ ($r = 0.976$, $p<0.01$, $df = 11$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant negative relationship between water content and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 21.78 – 1.79X$ ($r = -0.988$, $p<0.01$, $df = 3$)

Stem: $Y = 18.66 – 1.57X$ ($r = -0.989$, $p<0.01$, $df = 3$)

Root: $Y = 17.31 – 1.43X$ ($r = -0.979$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 16.87 – 1.47X$ ($r = -0.982$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water content of tissues (g g^{-1} dry weight).

A significant negative relationship was obtained between water potential and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = -0.76 – 2.02X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Stem: $Y = 4.54 – 1.09X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Root: $Y = 2.85 – 1.11X$ ($r = -0.972$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 2.86 – 1.79X$ ($r = -0.998$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water potential of tissues (-MPa).

Variety GHB 734

Proline content (μmol g^{-1} FW) of leaves, stems and roots significantly increased ($p<0.01$) as the age of control and salt-stressed plants increased (Fig. 34). Proline content in tissues significantly increased ($p<0.01$) in response to increase in soil salinity. Moreover, proline content in tissues of salt-stressed plants was consistently greater than that in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants proline content was maximum in leaves and minimum in roots at all the growth stages. There was a significant positive relationship between proline content of tissues at 12-week growth stage and salt concentration in soil according to the following expressions:

Leaf: $Y = 13.24 + 0.40X$ ($r = 0.963$, $p<0.01$, $df = 11$)

Stem: $Y = 11.22 + 0.39X$ ($r = 0.952$, $p<0.01$, $df = 11$)

Root: $Y = 10.68 + 0.31X$ ($r = 0.911$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 10.37 + 0.29X$ ($r = 0.942$, $p<0.01$, $df = 11$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant negative relationship between water content and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 20.58 – 1.71X$ ($r = -0.970$, $p<0.01$, $df = 3$)

Stem: $Y = 17.46 – 1.66X$ ($r = -0.985$, $p<0.01$, $df = 3$)

Root: $Y = 15.84 – 1.17X$ ($r = -0.984$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 14.92 – 1.09X$ ($r = -0.987$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water content of tissues (g g^{-1} dry weight).

A significant negative relationship was obtained between water potential and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 8.32 – 0.97X$ ($r = -0.995$, $p<0.01$, $df = 3$)

Stem: $Y = 6.49 – 0.86X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Root: $Y = 5.89 – 0.73X$ ($r = -0.951$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 6.44 – 0.74X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water potential of tissues (-MPa).

Variety GHB 743

Proline content (μmol g^{-1} FW) of leaves, stems and roots significantly increased ($p<0.01$) as the age of control and salt-stressed plants increased (Fig. 35). Proline content in tissues significantly increased ($p<0.01$) in response to increase in soil salinity. Moreover, proline content in tissues of salt-stressed plants was consistently greater than that in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants proline content was maximum in leaves and minimum in roots at all the growth stages. There was a significant positive relationship between proline content of tissues at 12-week growth stage and salt concentration in soil according to the following expressions:

Leaf: $Y = 12.59 + 0.36X$ ($r = 0.864$, $p<0.01$, $df = 11$)

Stem: $Y = 10.62 + 0.39X$ ($r = 0.882$, $p<0.01$, $df = 11$)

Root: $Y = 8.25 + 0.28X$ ($r = 0.919$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 7.96 + 0.19X$ ($r = 0.875$, $p<0.01$, $df = 11$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is salt concentration in soil (dS m^{-1}).

There was a significant negative relationship between water content and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 19.14 – 1.53X$ ($r = -0.977$, $p<0.01$, $df = 3$)

Stem: $Y = 16.77 – 1.63X$ ($r = -0.995$, $p<0.01$, $df = 3$)

Root: $Y = 12.74 – 1.02X$ ($r = -0.974$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 10.93 – 0.72X$ ($r = -0.973$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water content of tissues (g g^{-1} dry weight).

A significant negative relationship was obtained between water potential and proline content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 8.19 – 0.83X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Stem: $Y = 5.65 – 0.92X$ ($r = -0.992$, $p<0.01$, $df = 3$)

Root: $Y = 3.02 – 0.85X$ ($r = -0.999$, $p<0.01$, $df = 3$)

Inflorescence: $Y = 5.80 – 0.40X$ ($r = -0.972$, $p<0.01$, $df = 3$)

Where Y is proline content (μmol g^{-1} FW) of tissues and X is water potential of tissues (-MPa).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in proline content of tissues (leaves, stems, roots and inflorescences) in response to salinity. In general, proline content was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

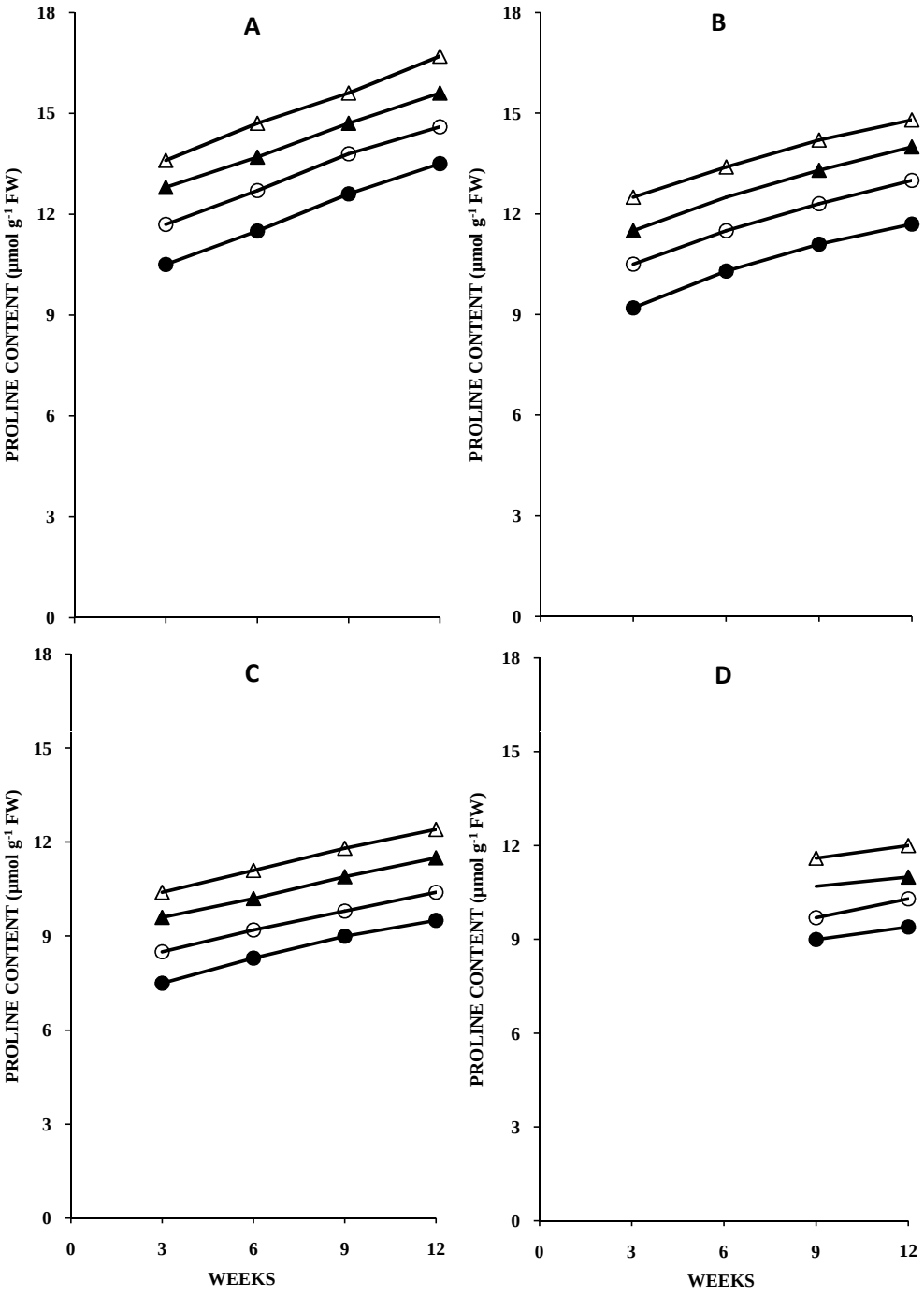

Fig. 31. Effect of soil salinity on proline content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

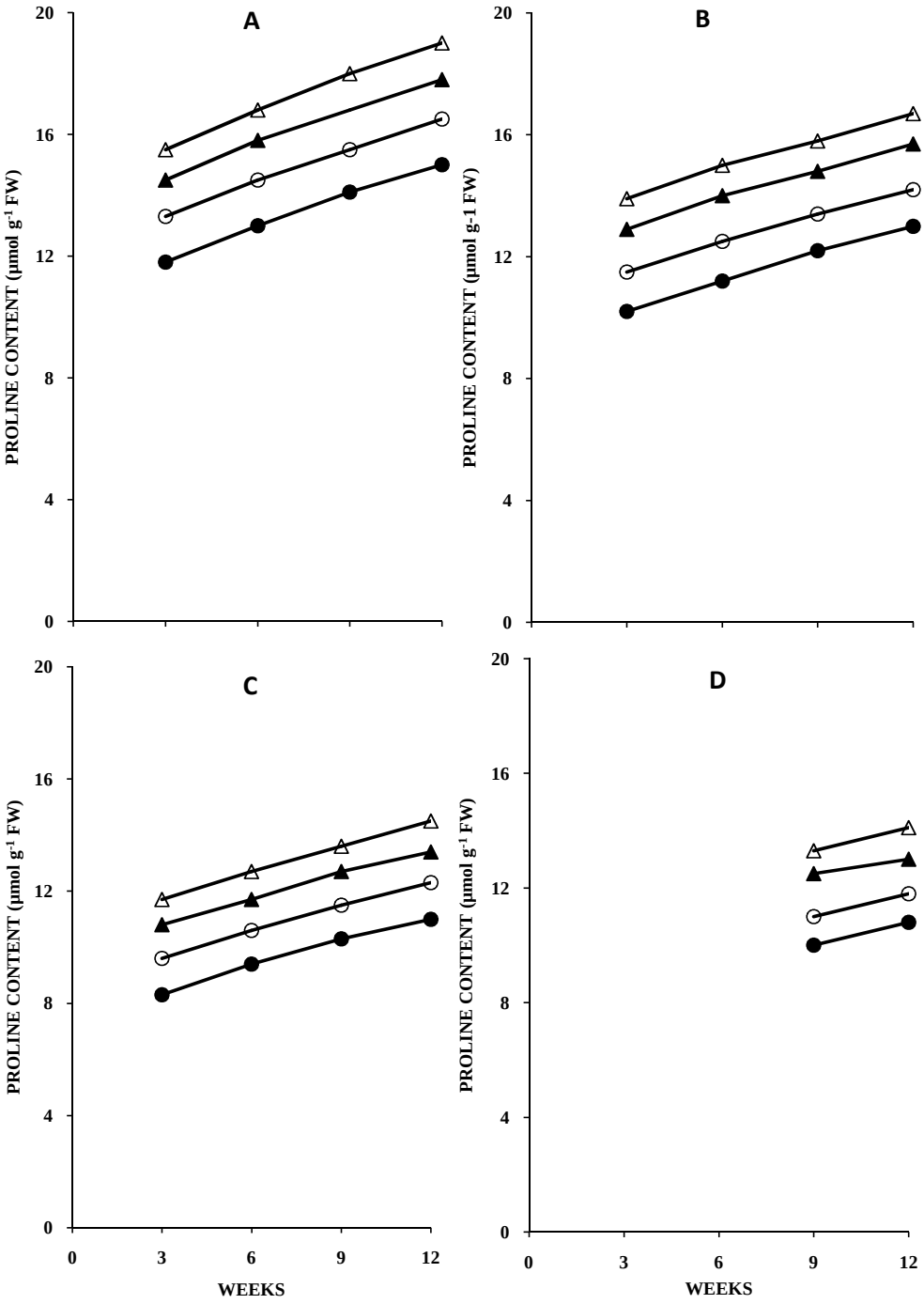

Fig. 32. Effect of soil salinity on proline content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

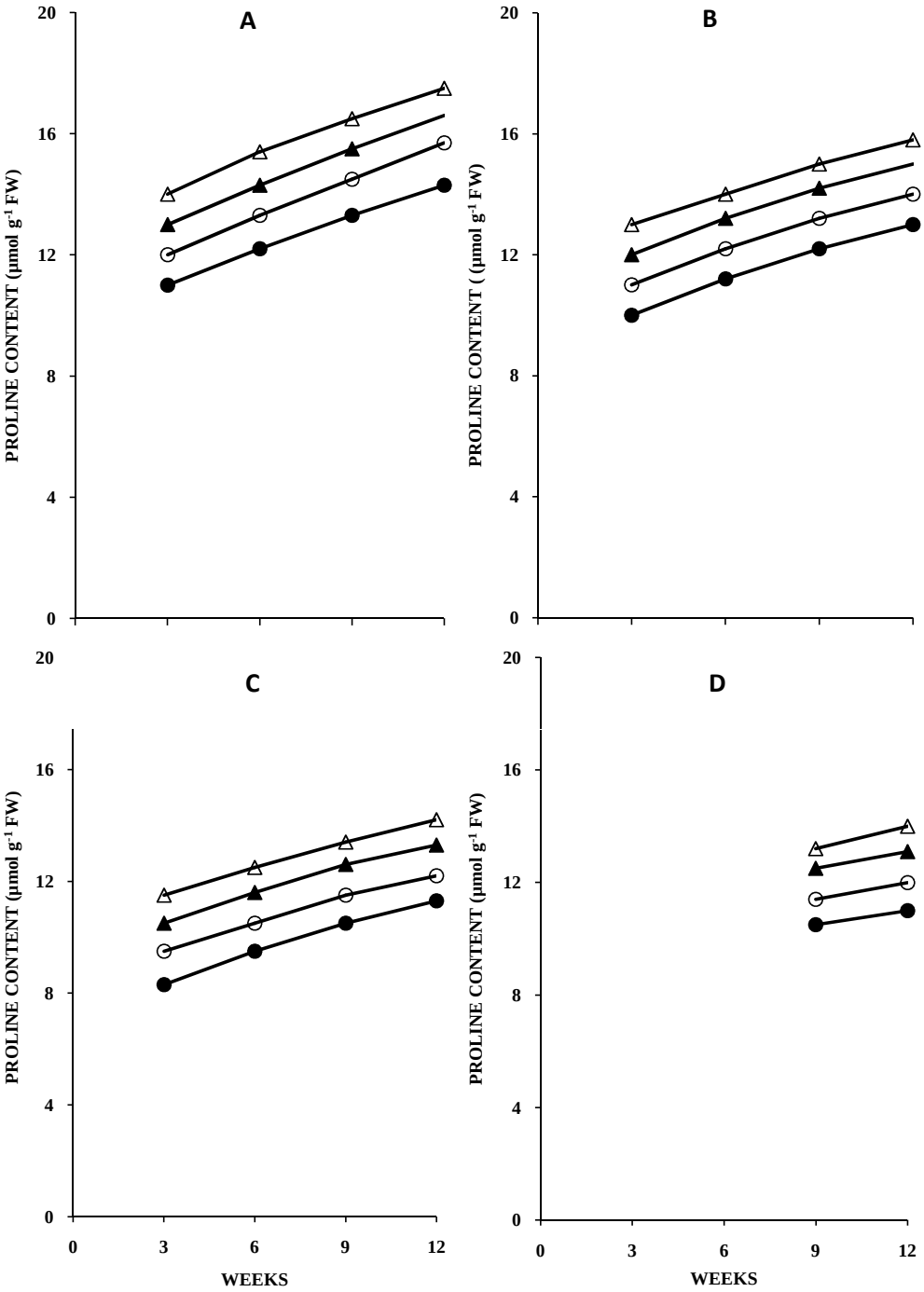

Fig. 33. Effect of soil salinity on proline content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

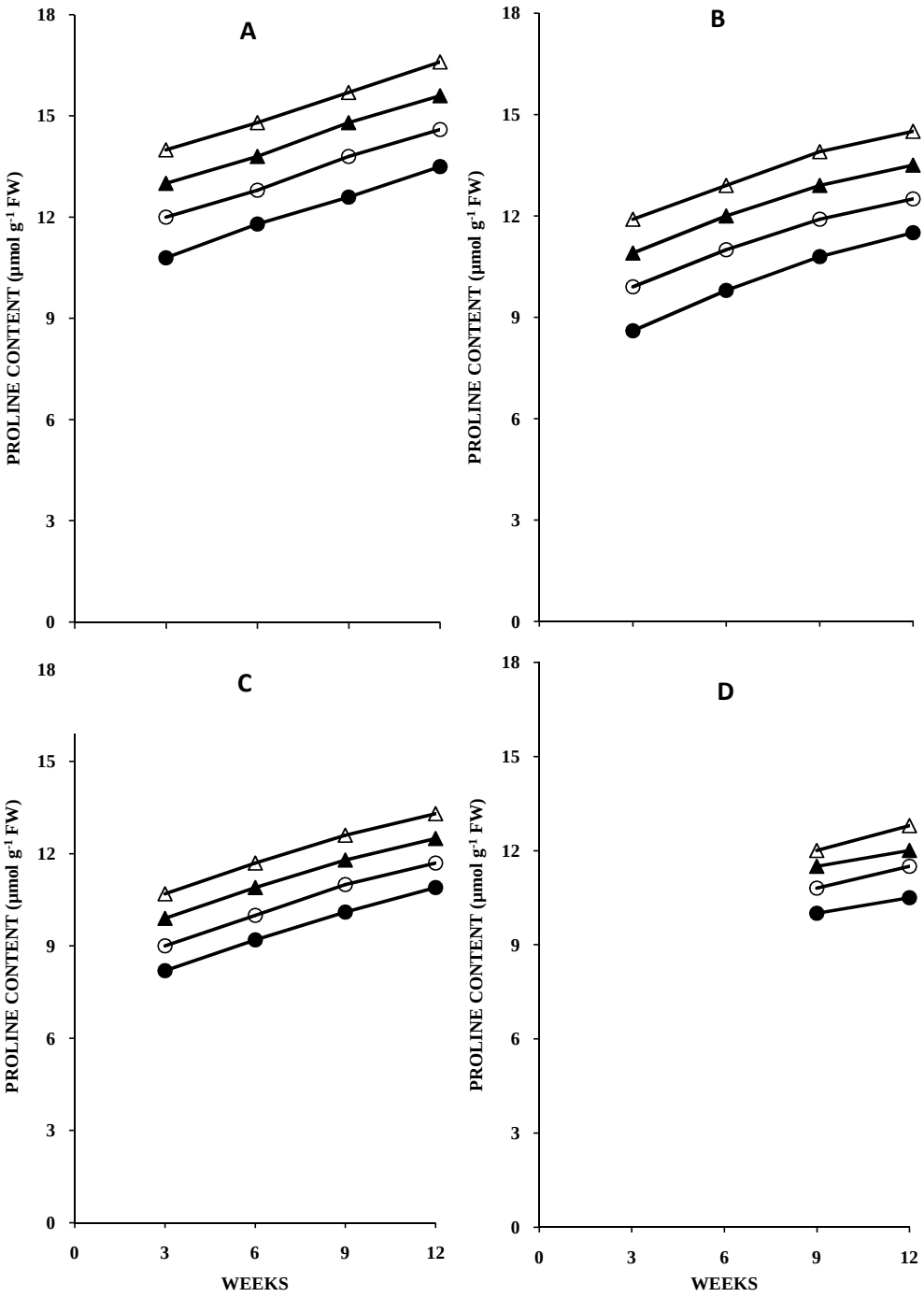

Fig. 34. Effect of soil salinity on proline content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

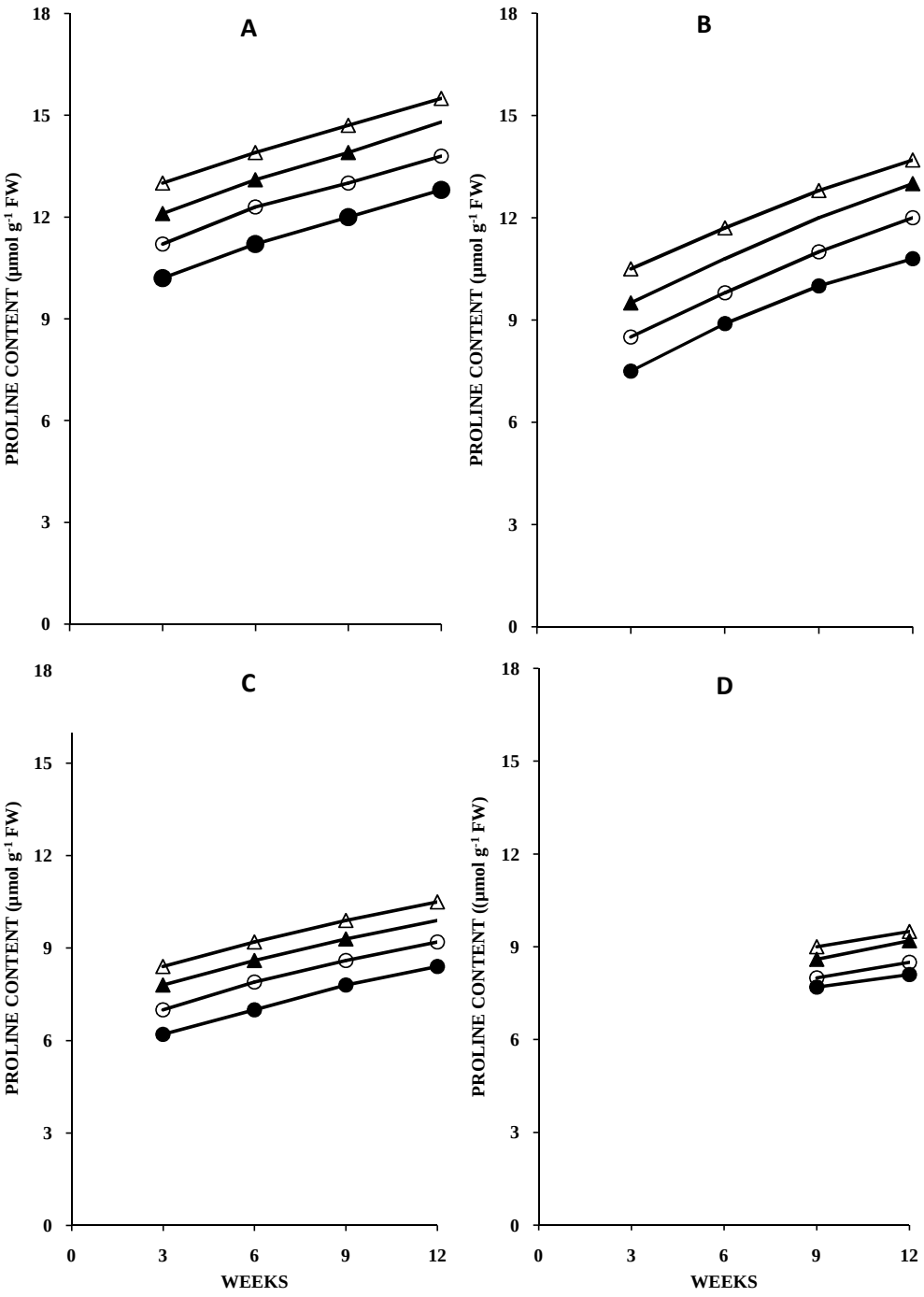

Fig. 35. Effect of soil salinity on proline content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Total carbohydrate in tissues

Variety GHB 538

As the age of control as well as salt-stressed plants advanced, total carbohydrate significantly increased ($p<0.01$) in leaves, stems and roots (Fig. 36). Moreover, increase in soil salinity significantly reduced ($p<0.01$) carbohydrate in tissues. As a result, carbohydrate was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants carbohydrate content was maximum in leaves and minimum in roots at all the growth stages. Carbohydrate in inflorescences for control as well as salt-stressed plants increased form 9-week to 12-week growth stage. Salt concentration significantly reduced ($p<0.01$) the concentration of carbohydrate in inflorescences. There was a significant negative relationship between soil salinity and carbohydrate in leaves, stems, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 626.21 – 10.21X$ ($r = -0.889$, $p<0.01$, $df = 11$)

Stem: $Y = 412.01 – 10.11X$ ($r = -0.886$, $p<0.01$, $df = 11$)

Root: $Y = 356.50 – 7.86X$ ($r = -0.955$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 640.72 – 13.5X$ ($r = -0.882$, $p<0.01$, $df = 11$)

Where, Y is concentration of carbohydrate (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 558

Total carbohydrate significantly increased ($p<0.01$) in leaves, stems and roots as the age of control as well as salt-stressed plants increased (Fig. 37). Increase in soil salinity caused a significant reduction ($P<0.01$) in carbohydrate of leaves, stems and roots. Carbohydrate was maximum in tissues of control plants, whereas, it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants carbohydrate content was maximum in leaves and minimum in roots at all the growth stages. Carbohydrate in inflorescences of both control and salt-stressed plants increased form 9-week to 12-week growth stage. Salt concentration significantly reduced ($p<0.01$) the concentration of carbohydrate in inflorescences. A significant negative relationship was obtained between soil salinity and carbohydrate in leaves, stems, roots and inflorescences at 12-week stage according to the following expressions:

Leaf: $Y = 596.73 – 11.38X$ ($r = -0.869$, $p<0.01$, $df = 11$)

Stem: $Y = 393.30 – 13.39X$ ($r = -0.948$, $p<0.01$, $df = 11$)

Root: $Y = 346.61 – 13.07X$ ($r = -0.829$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 596.71 – 11.38X$ ($r = -0.849$, $p<0.01$, $df = 11$)

Where, Y is concentration of carbohydrate (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 577

As the age of control and salt-stressed plants increased, total carbohydrate significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Fig. 38). In addition, carbohydrate significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Carbohydrate was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants carbohydrate content was maximum in leaves and minimum in roots at all the growth stages. Carbohydrate in inflorescences for control as well as salt-stressed plants increased from 9-week to 12-week growth stage. Salt concentration significantly reduced ($p<0.05$) the concentration of carbohydrate in inflorescences. A negative relationship was found between carbohydrate in leaves, stems, roots and inflorescences at 12-week growth stage and soil salinity according to the following expressions:

Leaf: $Y = 559.82 – 11.57X$ ($r = -0.896$, $p<0.01$, $df = 11$)

Stem: $Y = 414.70 – 11.1X$ ($r = -0.865$, $p<0.01$, $df = 11$)

Root: $Y = 316.23 – 10.21X$ ($r = -0.902$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 559.61 – 12.08X$ ($r = -0.858$, $p<0.01$, $df = 11$)

Where, Y is concentration of carbohydrate (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 734

Total carbohydrate significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Fig. 39). Increase in soil salinity significantly reduced ($p<0.01$) carbohydrate in leaves, stems and roots. Consequently, carbohydrate was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants carbohydrate content was maximum in leaves and minimum in roots at all the growth stages. Carbohydrate in inflorescences for control as well as salt-stressed plants increased from 9-week to 12-week growth stage. Salt concentration significantly reduced ($p<0.01$) the concentration of carbohydrate in inflorescences. A significant negative relationship was obtained between soil salinity and carbohydrate in leaves, stems, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 622.11 – 13.02X$ ($r = -0.929$, $p<0.01$, $df = 11$)

Stem: $Y = 522.12 – 13.34X$ ($r = -0.835$, $p<0.01$, $df = 11$)

Root: $Y = 326.20 – 10.21X$ ($r = -0.789$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 629.92 – 14.40X$ ($r = -0.959$, $p<0.01$, $df = 11$)

Where, Y is concentration of carbohydrate (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 743

Total carbohydrate significantly increased ($p<0.01$) in leaves, stems and roots as the age of control as well as salt-stressed plants increased (Fig. 40). Further, carbohydrate in tissues significantly decreased ($p<0.01$) in response to increase in soil salinity. As a result, carbohydrate was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants carbohydrate content was maximum in leaves and minimum in roots at all the growth stages. Total carbohydrate in inflorescences of both control and salt-stressed plants increased from 9 to 12-week growth stage. Salt concentration significantly reduced ($p<0.01$) the concentration of carbohydrate in inflorescences. There was a significant negative relationship between carbohydrate in leaves, stems, roots and inflorescences at 12-week growth stage and soil salinity according to the following expressions:

Leaf: $Y = 689.51 – 14.70X$ ($r = -0.986$, $p<0.01$, $df = 11$)

Stem: $Y = 567.92 – 18.37X$ ($r = -0.990$, $p<0.01$, $df = 11$)

Root: $Y = 442.43 – 12.37X$ ($r = -0.908$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 698.50 – 13.04X$ ($r = -0.912$, $p<0.01$, $df = 11$)

Where, Y is concentration of carbohydrate (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in total carbohydrate in tissues (leaves, stems, roots and inflorescences) in response to salinity. In addition, concentration of carbohydrate was greater in tissues of varieties GHB 734 and GHB 743 than that in tissues of varieties GHB 538, GHB 558 and GHB 577.

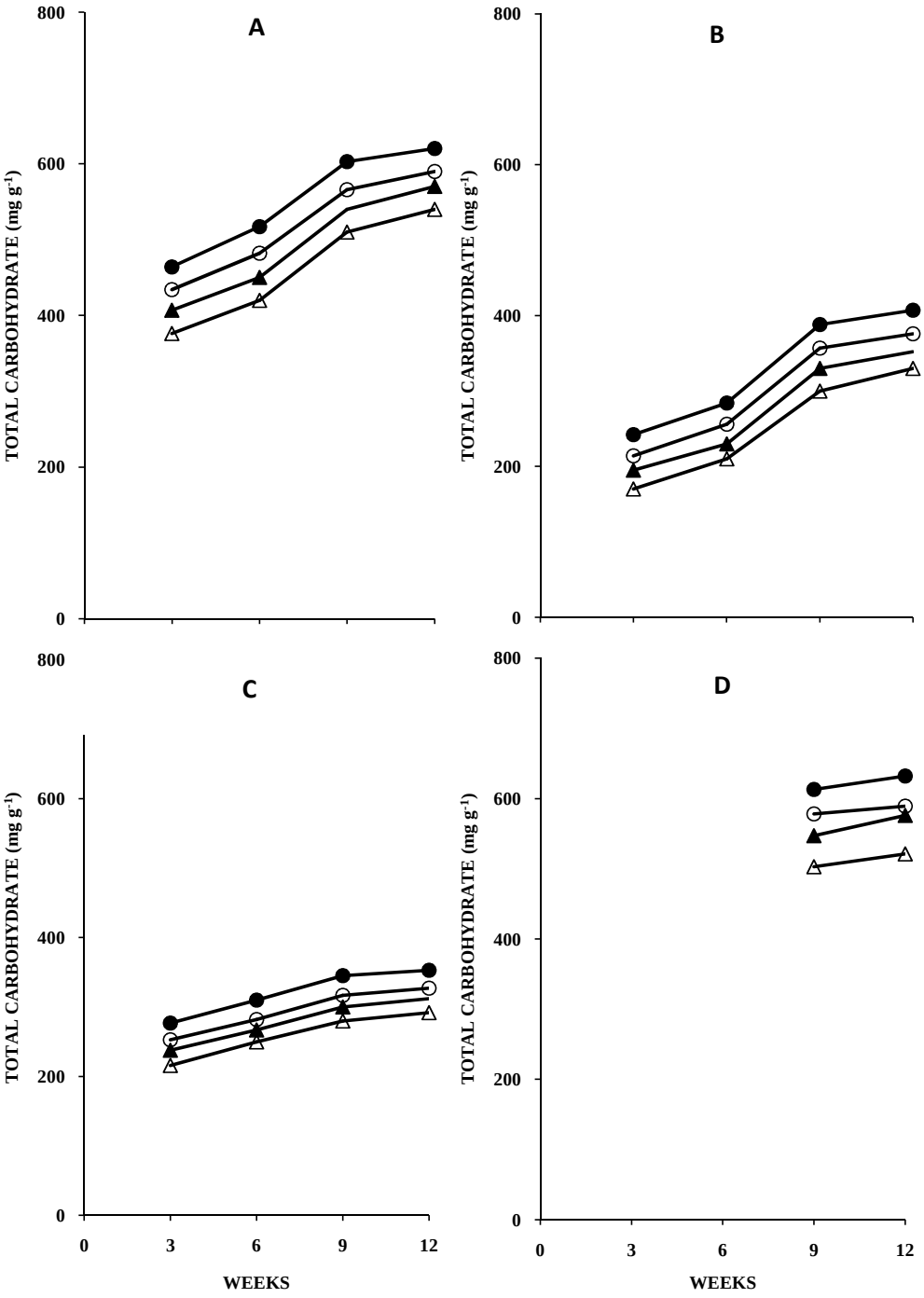

Fig. 36. Effect of soil salinity on total carbohydrate of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

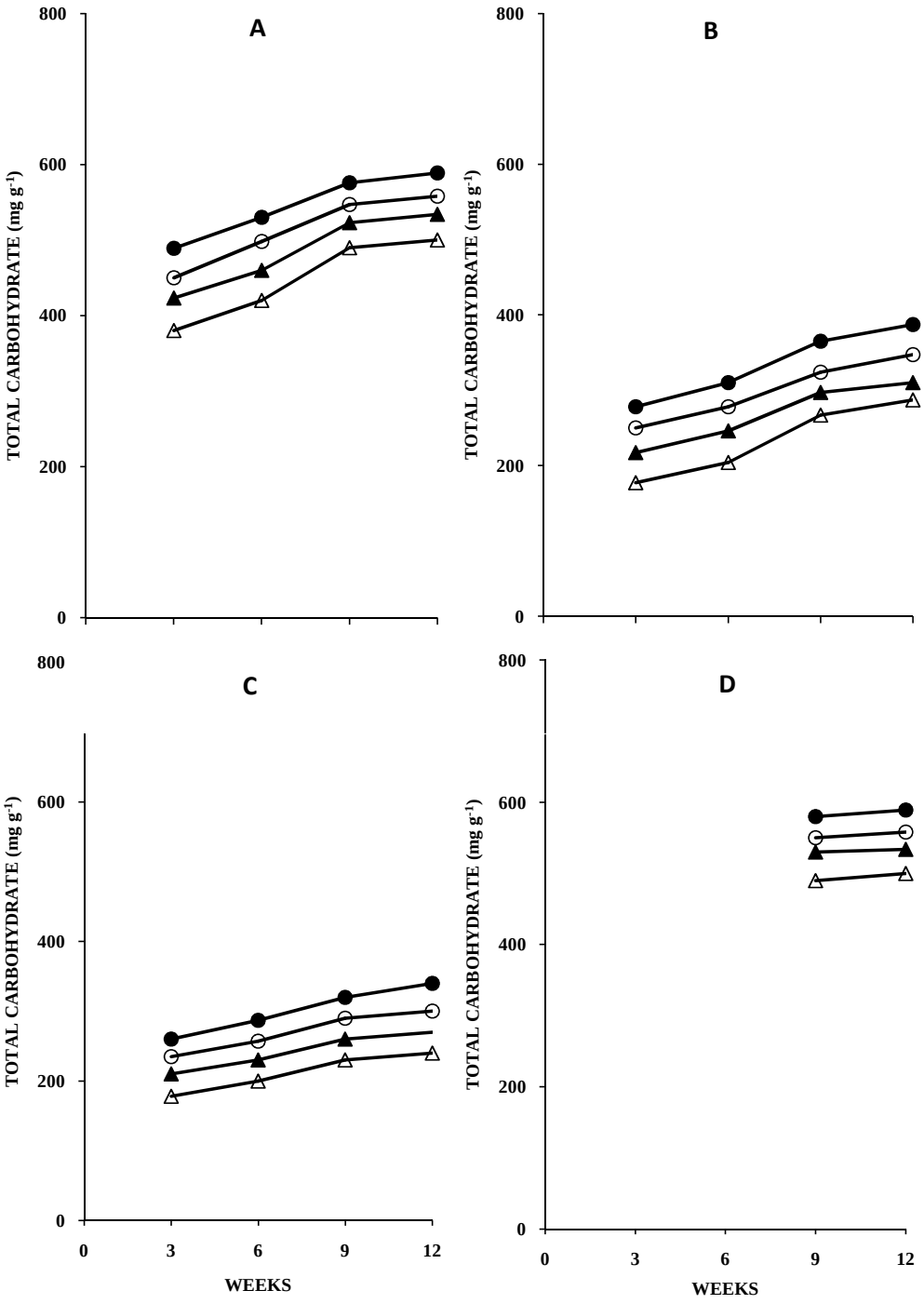

Fig. 37. Effect of soil salinity on total carbohydrate of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

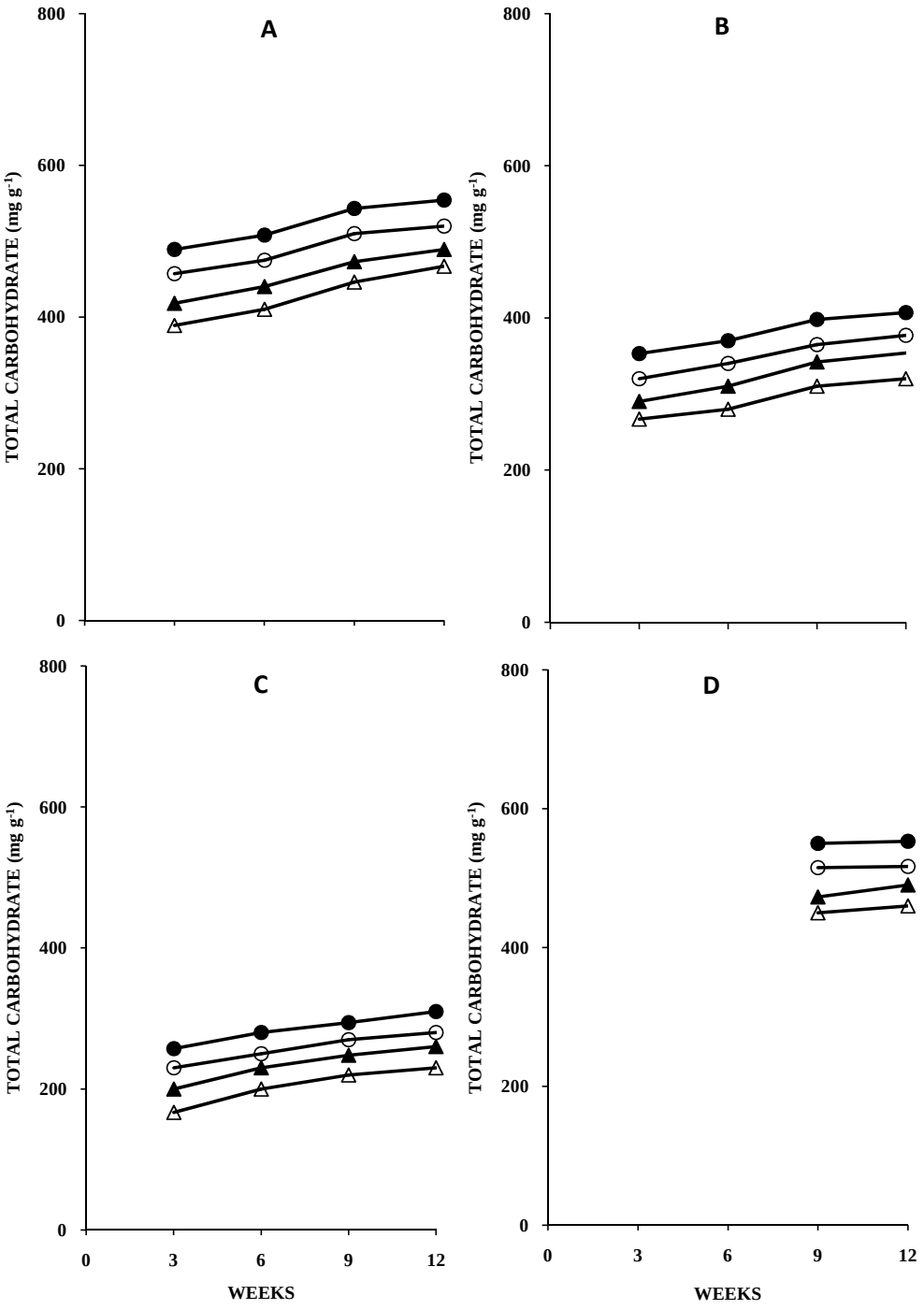

Fig. 38. Effect of soil salinity on total carbohydrate of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

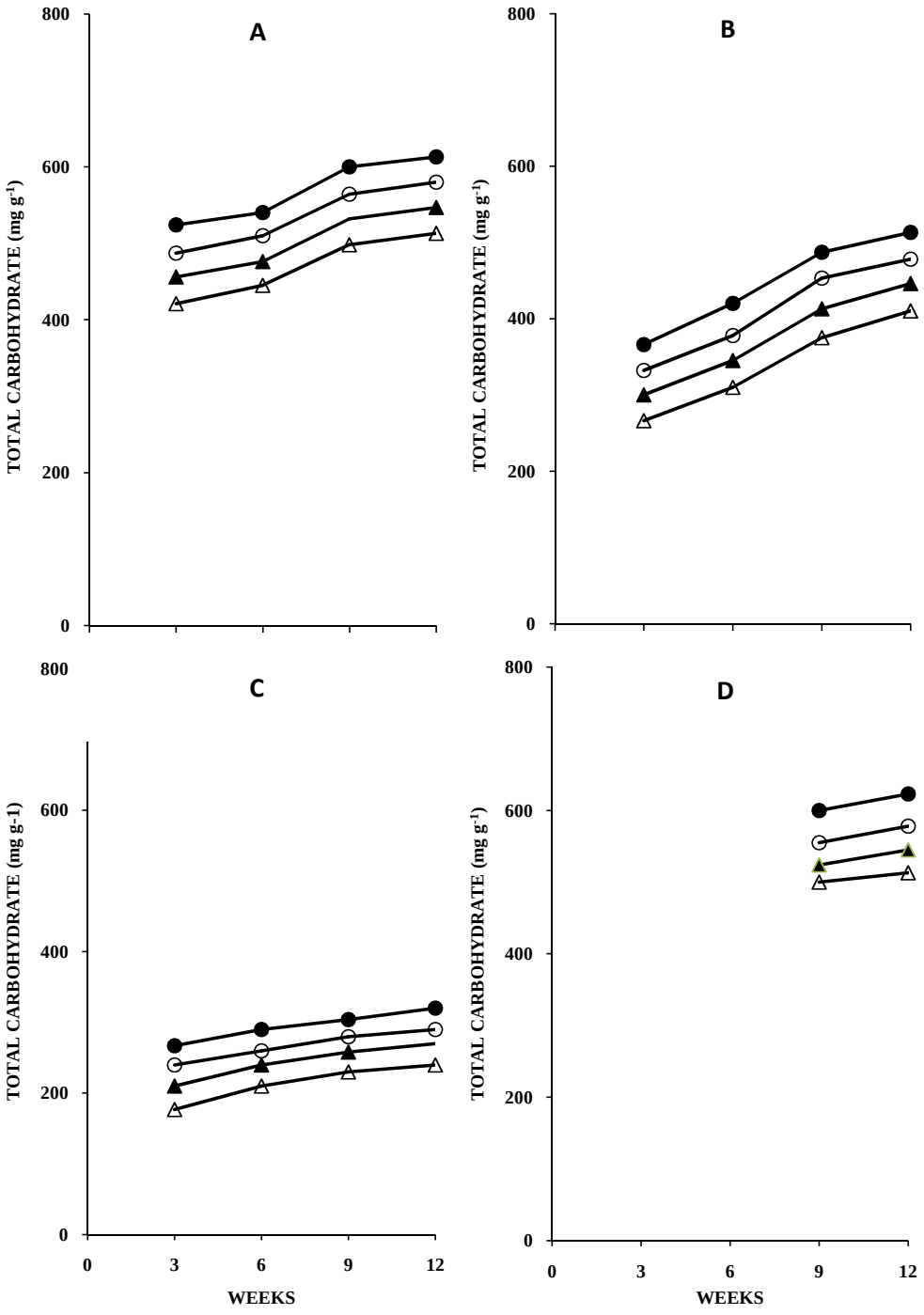

Fig. 39. Effect of soil salinity on total carbohydrate of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

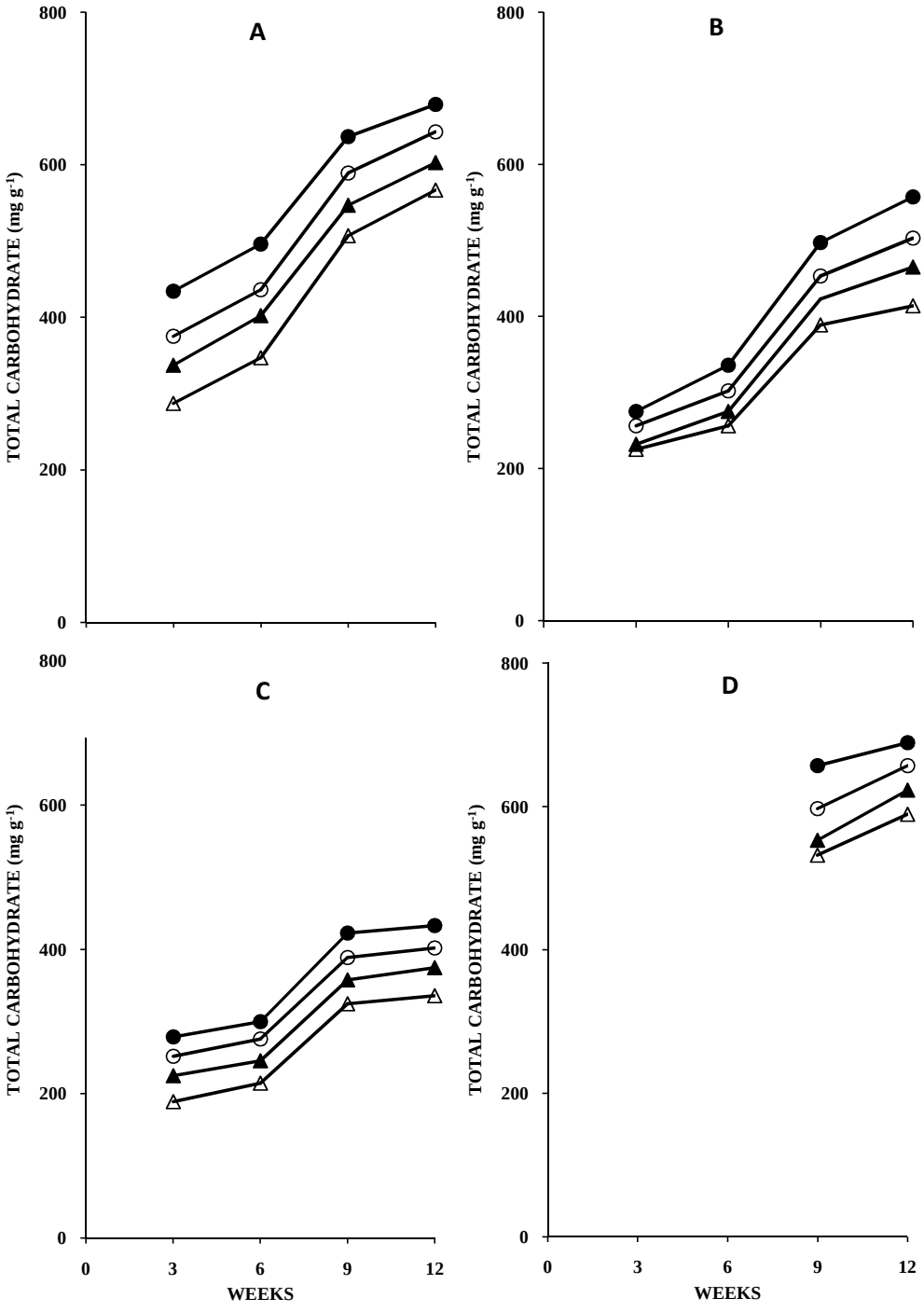

Fig. 40. Effect of soil salinity on total carbohydrate of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS $m^{-1;}$ (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Protein content in tissues

Variety GHB 538

Protein content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control as well as salt-stressed plants increased (Fig. 41). Increase in soil salinity caused a significant reduction ($p<0.01$) in protein content of leaves, stems and roots. Protein content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt stressed plants protein content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and protein content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 101.40 – 2.19X$ ($r = -0.887$, $p<0.01$, $df = 11$)

Stem: $Y = 88.54 – 1.78X$ ($r = -0.727$, $p<0.01$, $df = 11$)

Root: $Y = 92.31 – 1.67X$ ($r = -0.793$, $p<0.01$, $df = 11$)

Where Y is protein content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in protein content in inflorescences with increase in soil salinity. Further, protein content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 558

As the age of control and salt-stressed plants increased, protein content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Fig. 42). In addition, protein content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Protein content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt stressed plants protein content was maximum in leaves and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and protein content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 111.51 – 2.77X$ ($r = -0.779$, $p<0.01$, $df = 11$)

Stem: $Y = 99.35 – 1.96X$ ($r = -0.925$, $p<0.01$, $df = 11$)

Root: $Y = 93.08 – 1.57X$ ($r = -0.767$, $p<0.01$, $df = 11$)

Where Y is protein content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Protein content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, protein content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 577

Protein content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Fig. 43). Increase in soil salinity significantly reduced ($p<0.01$) protein content in tissues. Consequently, protein content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt stressed plants protein content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was found between soil salinity and protein content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 104.20 – 2.33X$ ($r = -0.892$, $p<0.01$, $df = 11$)

Stem: $Y = 98.31 – 1.67X$ ($r = -0.858$, $p<0.01$, $df = 11$)

Root: $Y = 92.16 – 1.80X$ ($r = -0.766$, $p<0.01$ $df = 11$)

Where Y is protein content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in protein content in inflorescences with increase in soil salinity. Protein content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 734

Protein content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control as well as salt-stressed plants increased (Fig. 44). Further, protein content in tissues significantly decreased ($p<0.01$) in response to increase in soil salinity. As a result, protein content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt stressed plants protein content was maximum in leaves and minimum in roots at all the growth stages. Protein content in inflorescences of both control and salt-stressed plants did not increase from 9 to 12-week growth stage. Salt concentration significantly reduced ($p<0.05$) the concentration of protein in inflorescences. There was a significant negative relationship between soil salinity and protein in leaves, stems, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 99.43 – 2.19X$ ($r = -0.878$, $p<0.01$ $df = 11$)

Stem: $Y = 95.16 – 1.80X$ ($r = -0.867$, $p<0.01$ $df = 11$)

Root: $Y = 90.08 – 1.56X$ ($r = -0.757$, $p<0.01$, $df = 11$)

Inflorescence: $Y = 99.89 – 1.41X$ ($r = -0.809$, $p<0.01$, $df = 11$)

Where Y is protein content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Variety GHB 743

As the age of control as well as salt-stressed plants advanced, protein content significantly increased ($p<0.01$) in leaves, stems and roots (Fig. 45). Moreover, increase in soil salinity significantly reduced ($p<0.01$) protein in tissues. As a result, protein was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants protein content was maximum in leaves and minimum in roots at all the growth stages. Protein content in inflorescences of both control and salt-stressed plants did not increase from 9 to 12-week growth stage. Salt concentration significantly reduced ($p<0.01$) the concentration of protein in inflorescences. There was a significant negative relationship between soil salinity and protein in leaves, stems, roots and inflorescences at 12-week growth stage according to the following expressions:

Leaf: $Y = 97.35 – 1.96X$ ($r = -0.959$, $p<0.01$, $df = 11$)

Stem: $Y = 94.31 – 1.67X$ ($r = -0.885$, $p<0.01$, $df = 11$)

Root: $Y = 88.32 – 0.96X$ ($r = -0.657$, $p<0.05$, $df = 11$)

Inflorescence: $Y = 98.08 – 1.57X$ ($r = -0.914$, $p<0.01$, $df = 11$)

Where, Y is protein content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in protein content in tissues (leaves, stems, roots and inflorescences) in response to salinity. In general, concentration of protein content was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

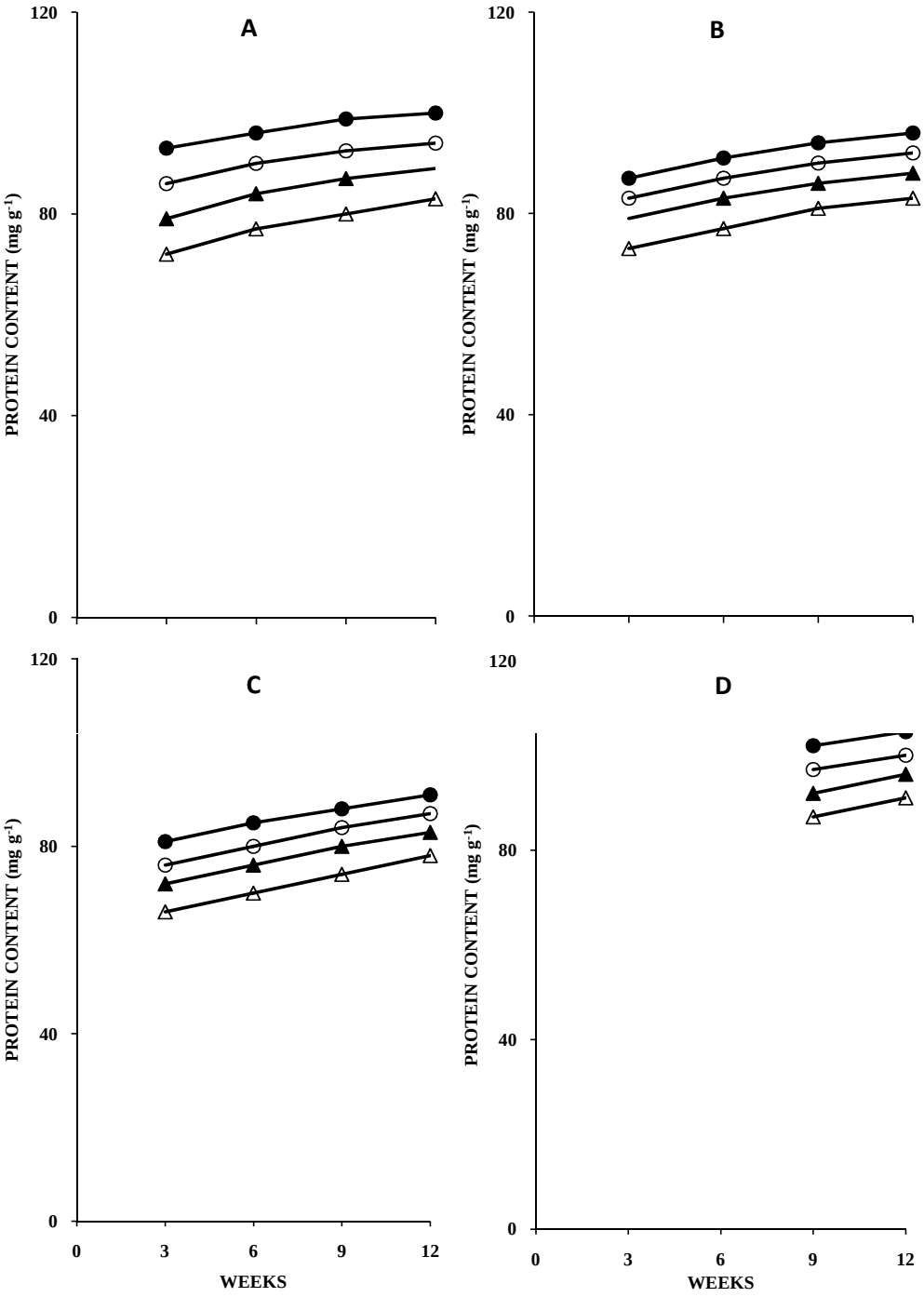

Fig. 41. Effect of soil salinity on protein content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

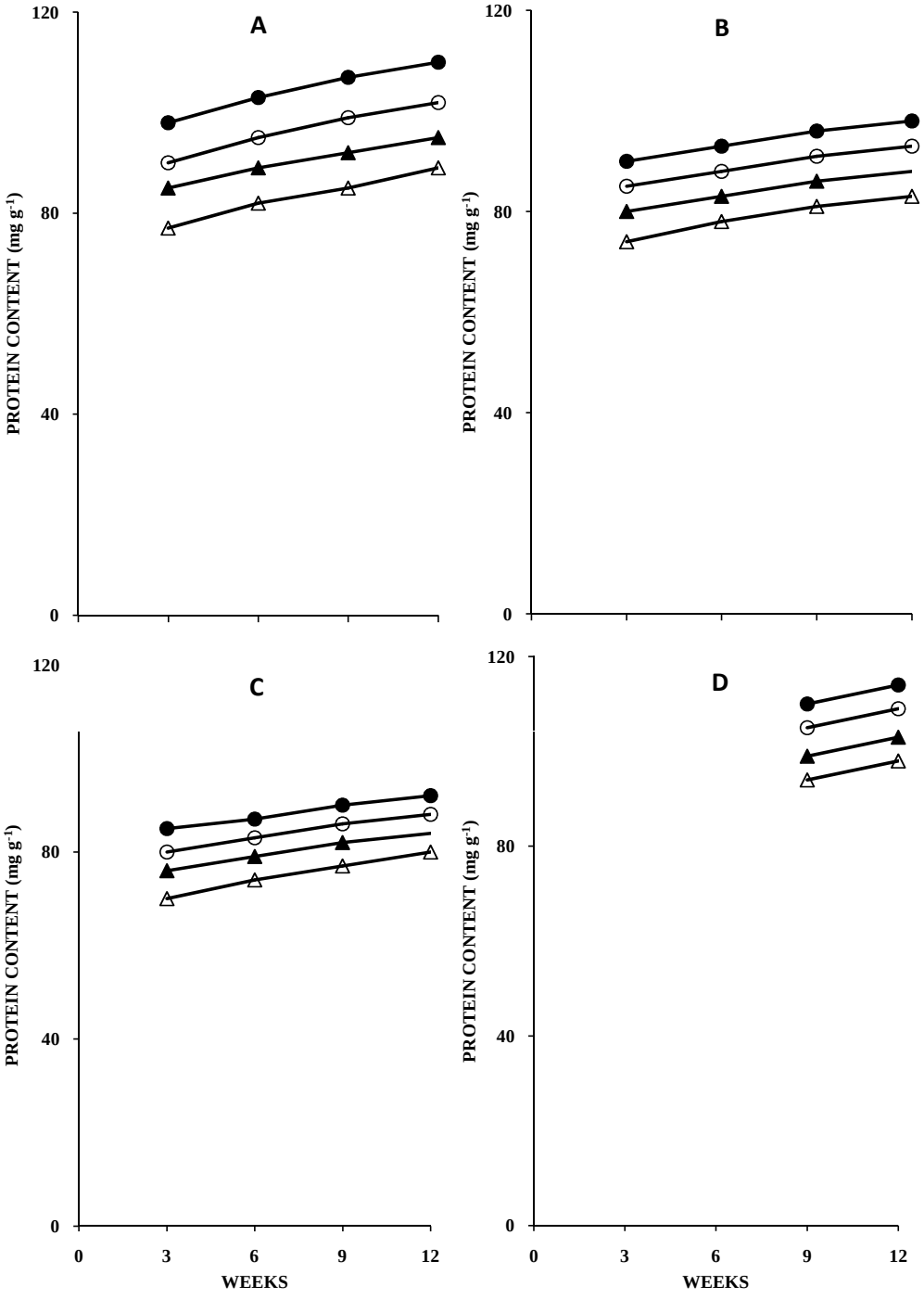

Fig. 42. Effect of soil salinity on protein content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

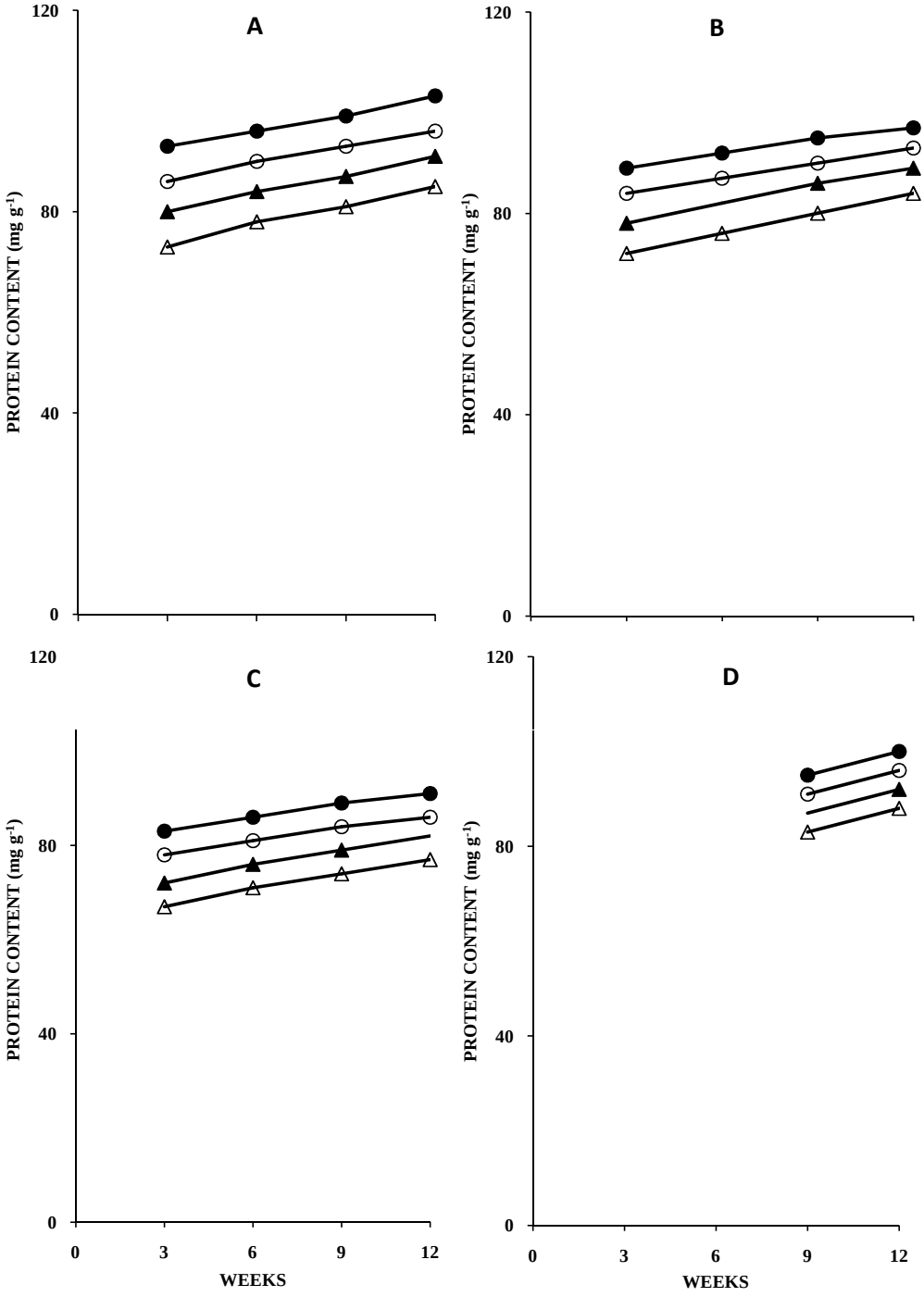

Fig. 43. Effect of soil salinity on protein content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

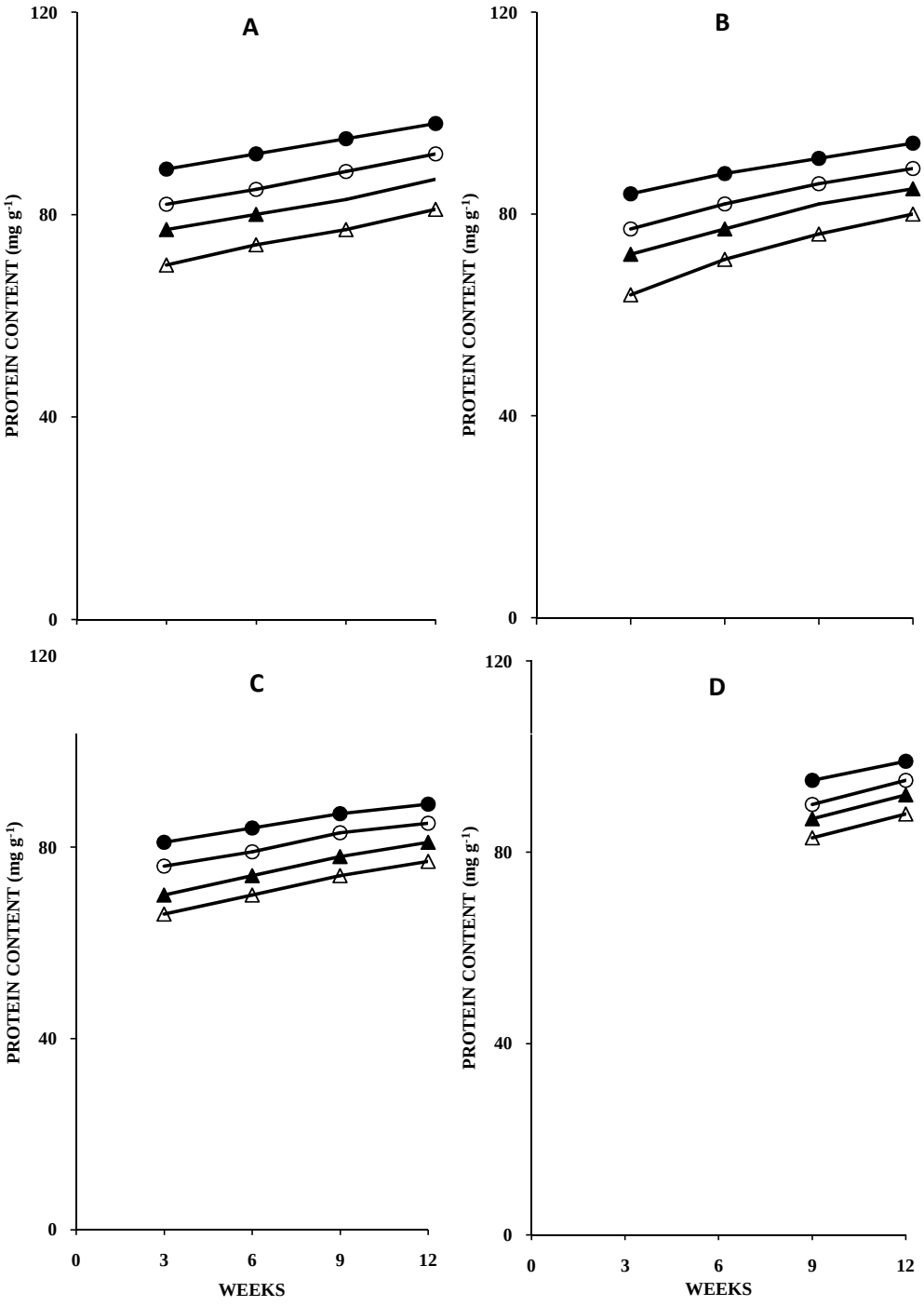

Fig. 44. Effect of soil salinity on protein content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

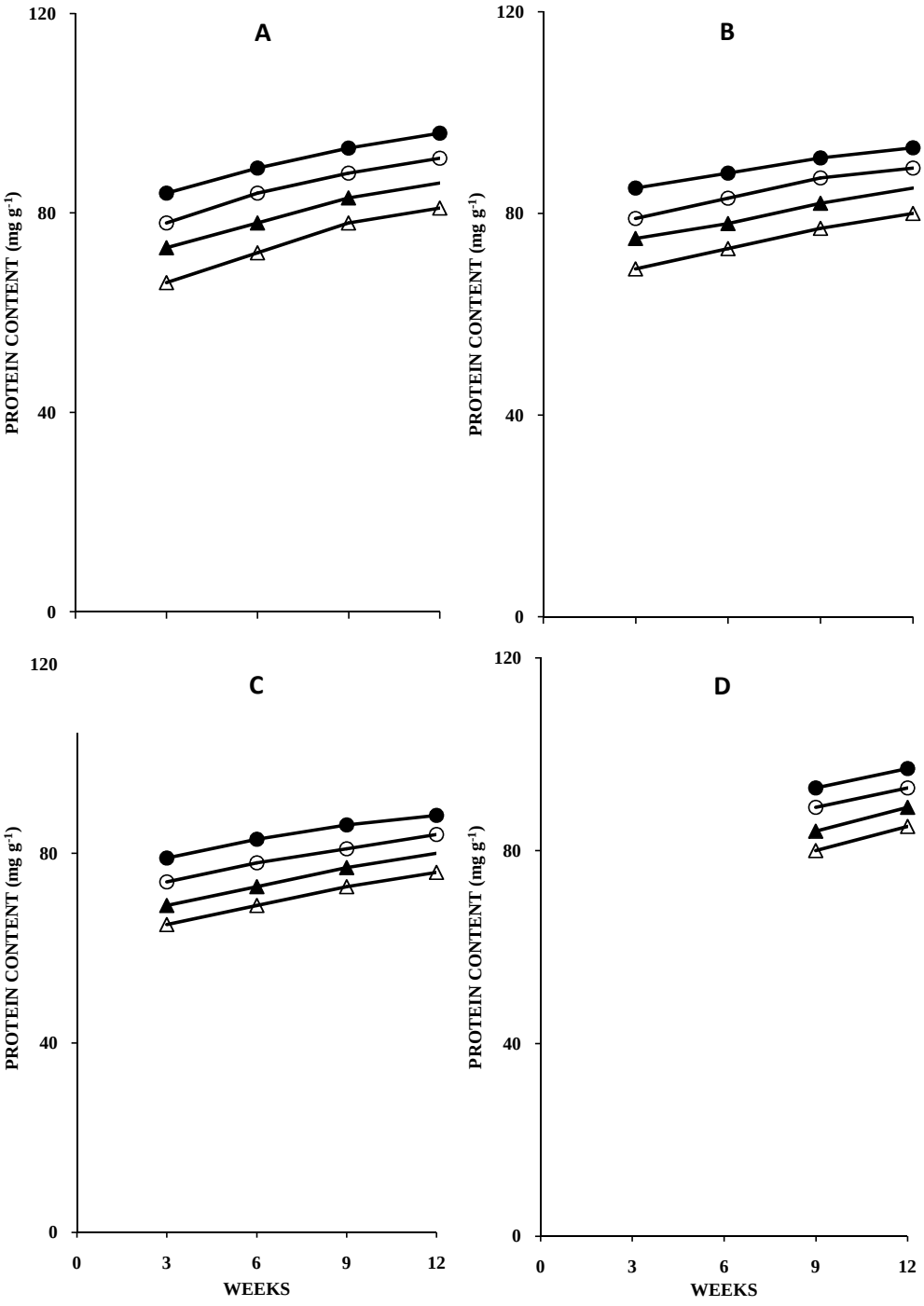

Fig. 45. Effect of soil salinity on protein content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Lipid content in tissues

Variety GHB 538

As the age of control and salt-stressed plants increased, lipid content significantly increased ($p<0.01$) in tissues (Fig. 46). In addition, lipid content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Lipid content was maximum in tissues of control plants and minimum in tissues of plants growth in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants lipid content was maximum in leaves and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and lipid content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 36.35 – 0.79X$ ($r = -0.642$, $p<0.05$, $df = 11$)

Stem: $Y = 30.54 – 0.78X$ ($r = -0.633$, $p<0.05$, $df = 11$)

Root: $Y = 25.48 – 0.64X$ ($r = -0.663$, $p<0.05$, $df = 11$)

Where, Y is lipid content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Lipid content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, lipid content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 558

Lipid content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) as the age of control as well as salt-stressed plants increased (Fig. 47). Increase in soil salinity significantly reduced ($p<0.01$) lipid content of leaves, stems and roots. Consequently, lipid was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants lipid content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and lipid content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 38.54 – 0.78X$ ($r = -0.561$, $p<0.05$, $df = 11$)

Stem: $Y = 33.54 – 0.78X$ ($r = -0.587$, $p<0.05$, $df = 11$)

Root: $Y = 28.33 – 0.65X$ ($r = -0.607$, $p<0.05$, $df = 11$)

Where, Y is lipid content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in lipid content in inflorescences with increase in soil salinity. Further, lipid content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 577

Lipid content significantly increased in leaves ($p<0.05$), stems and roots ($p<0.01$) as the age of control as well as salt-stressed plants increased (Fig. 48). Further, lipid content significantly decreased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) in response to increase in soil salinity. As a result, lipid content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants lipid content was maximum in leaves and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and lipid content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 36.61 – 0.81X$ ($r = -0.613$, $p<0.05$, $df = 11$)

Stem: $Y = 30.81 – 0.68X$ ($r = -0.648$, $p<0.05$, $df = 11$)

Root: $Y = 26.04 – 0.78X$ ($r = -0.597$, $p<0.05$, $df = 11$)

Where, Y is lipid content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

Lipid content in inflorescences did not decrease with increase in soil salinity. Moreover, lipid content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 734

As the age of control and salt-stressed plants advanced, lipid content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) (Fig. 49). Moreover, increase in soil salinity significantly reduced ($p<0.01$) lipid content in tissues. As a result, lipid content was maximum in tissues of control plants and minimum in tissues of plants growth in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants lipid content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and lipid content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 34.07 – 0.77X$ ($r = -0.574$, $p<0.05$, $df = 11$)

Stem: $Y = 27.54 – 0.78X$ ($r = -0.637$, $p<0.05$, $df = 11$)

Root: $Y = 24.44 – 0.71X$ ($r = -0.616$, $p<0.05$, $df = 11$)

Where, Y is lipid content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in lipid content in inflorescences with increase in soil salinity. Lipid content in inflorescences was almost similar at 9 and 12-week growth stages.

Variety GHB 743

Lipid content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.05$) as the age of control as well as salt-stressed plants increased (Fig. 50). Increase in soil salinity caused a significant reduction ($p<0.01$) in lipid content of leaves, stems and roots. Lipid content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants lipid content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and lipid content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 32.58 – 1.07X$ ($r = -0.737$, $p<0.01$, $df = 11$)

Stem: $Y = 28.37 – 0.77X$ ($r = -0.686$, $p<0.01$, $df = 11$)

Root: $Y = 23.54 – 0.78X$ ($r = -0.559$, $p<0.05$, $df = 11$)

Where, Y is lipid content (mg g^{-1}) in tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in lipid content in inflorescences with increase in soil salinity. Further, lipid content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties in lipid content in tissues (leaves, stems, roots and inflorescences) in response to salinity. In general, concentration of lipid content was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

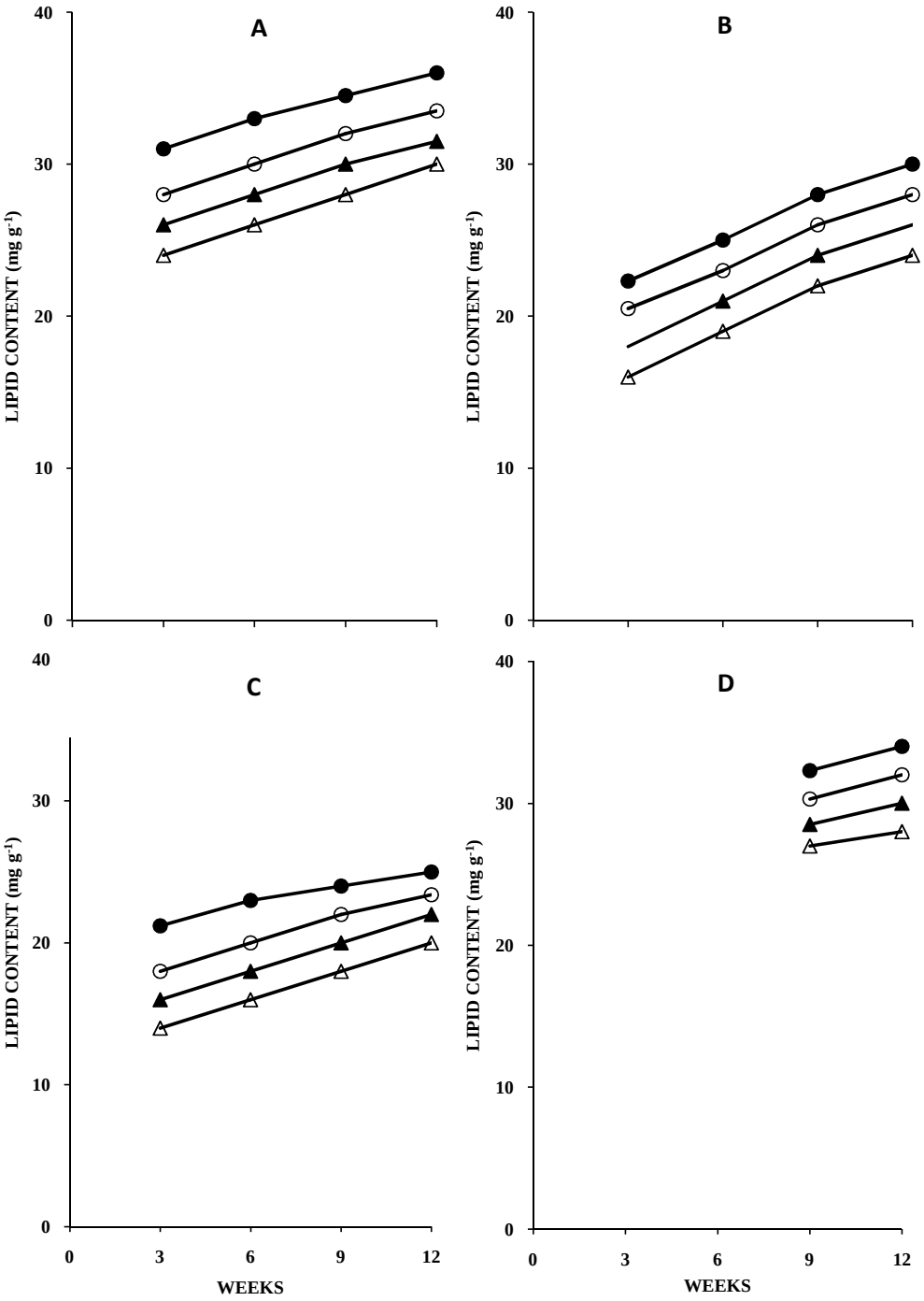

Fig. 46. Effect of soil salinity on lipid content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 538** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

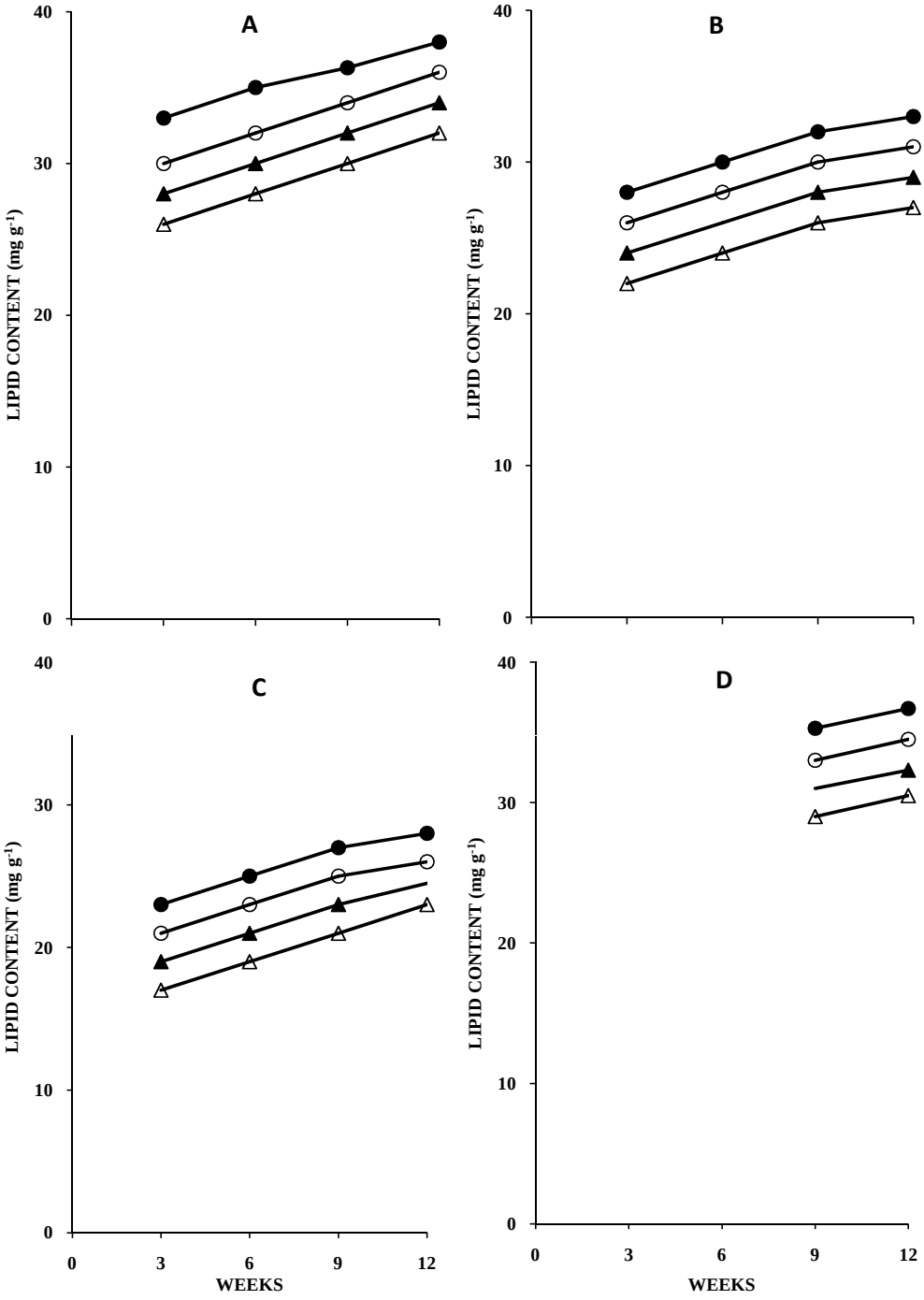

Fig. 47. Effect of soil salinity on lipid content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 558** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

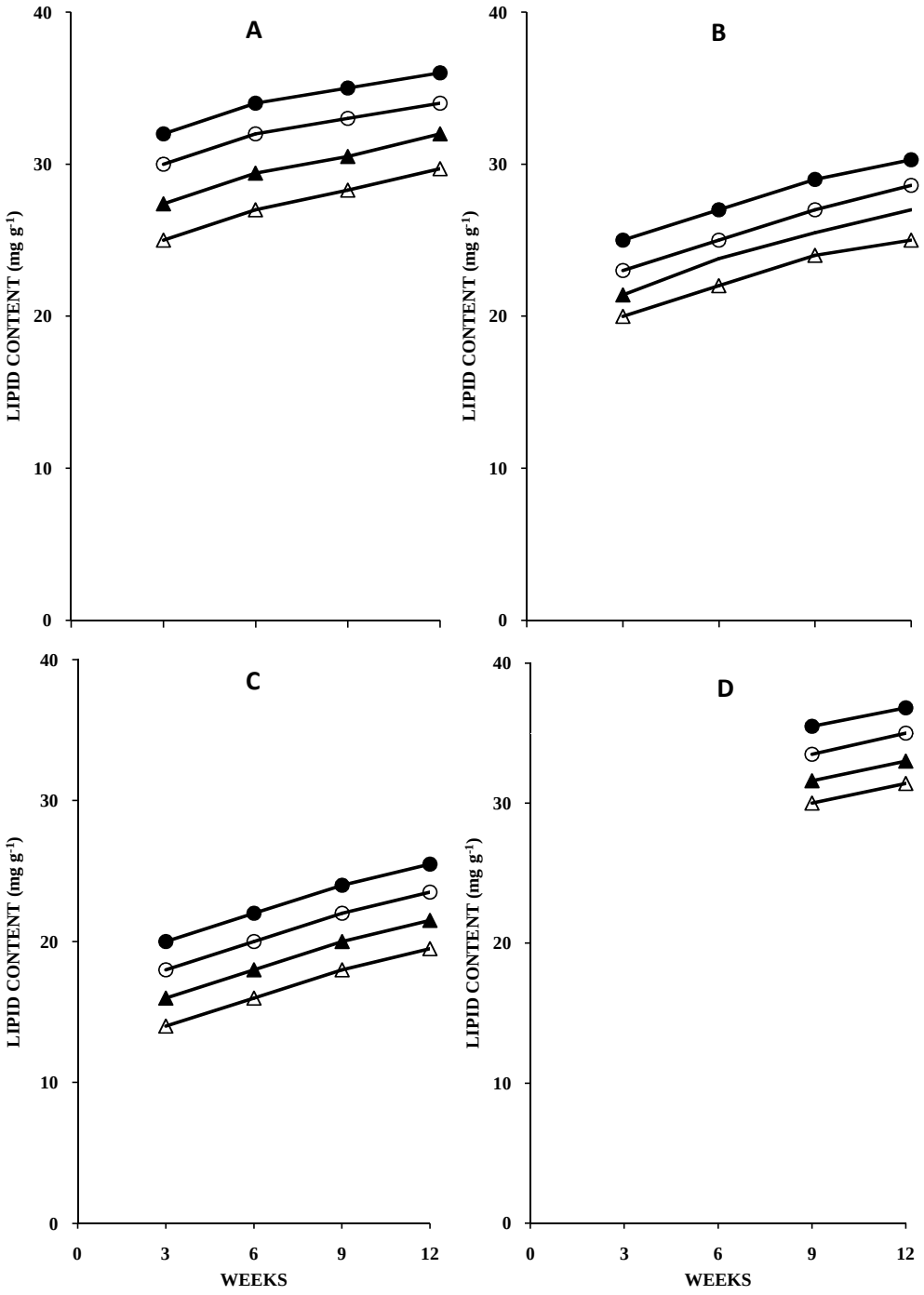

Fig. 48. Effect of soil salinity on lipid content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 577** at different growth stages. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

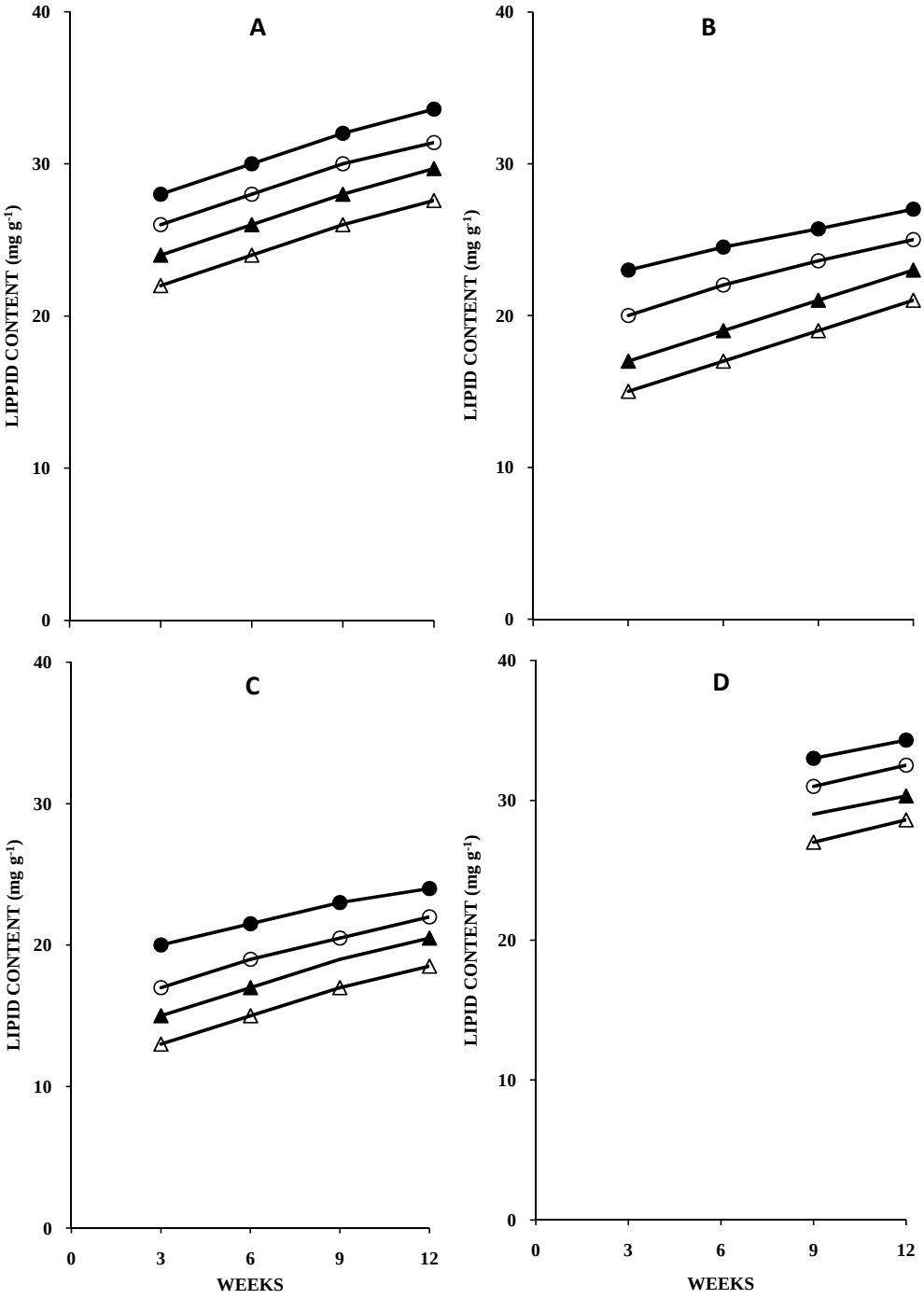

Fig. 49. Effect of soil salinity on lipid content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 734** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

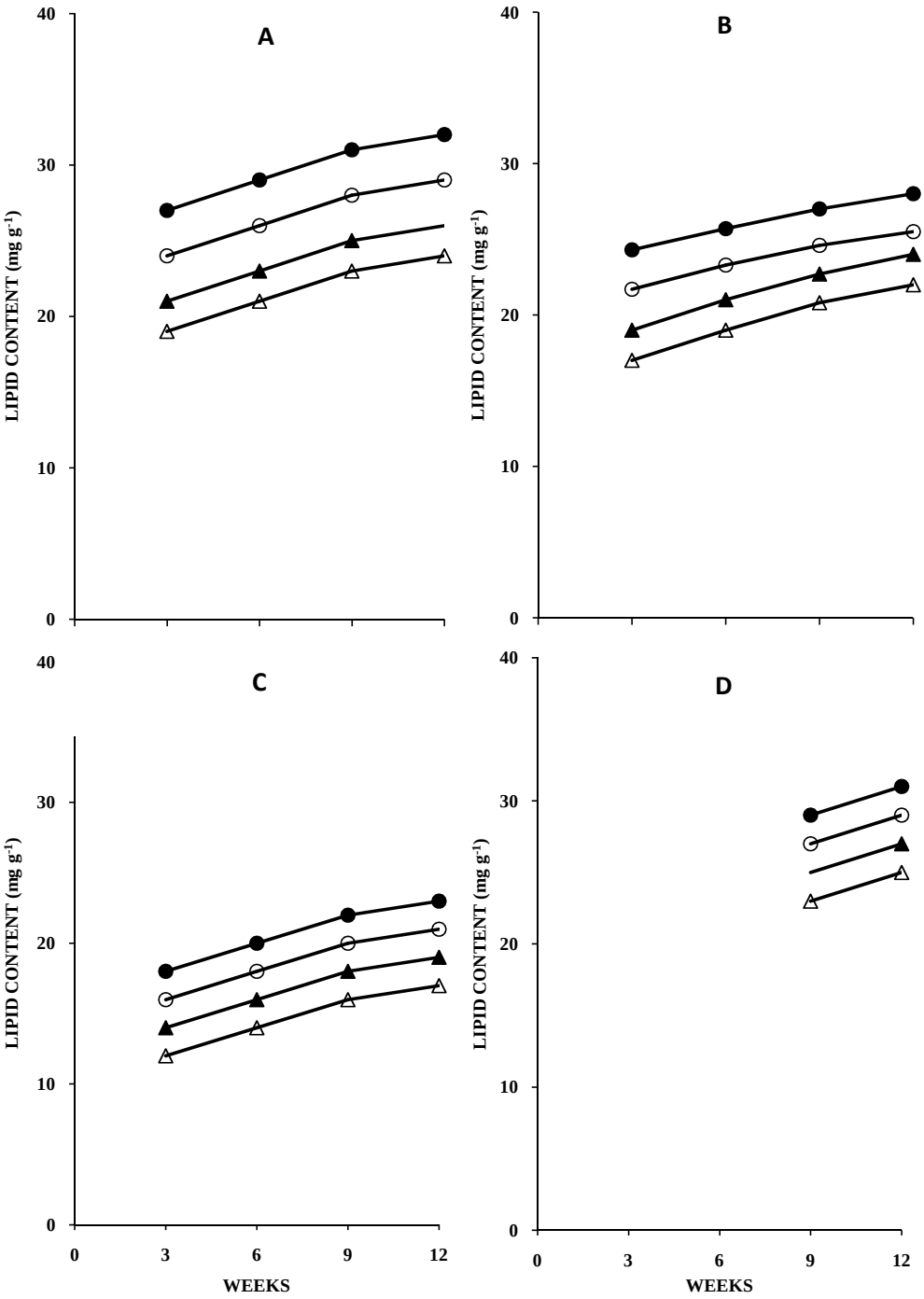

Fig. 50. Effect of soil salinity on lipid content of **A.** leaf, **B**. stem, **C**. root and **D.**inflorescence of *Pennisetum glaucum L.* variety **GHB 743** over time. (●),0.3dS m^{-1}; (○),3.9dS m^{-1}; (▲),6.0dS m^{-1} and (Δ),7.9dS m^{-1}. Error bars represent SE.

Effect of Salinity on Nutrient Accumulation in Tissues

Variety GHB 538

Effect of Salinity on Sodium and Potassium Content and K/Na Ratio in Tissues.

Na content in tissues

As the age of control and salt-stressed plants increased, sodium content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Table 1). In addition, Na content in leaves and roots significantly increased ($p<0.01$) with increase of salt concentration in soil. There was no significant increase in Na content in stems with increase of salt concentration in soil. Sodium content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Na content was maximum in leaves and minimum in roots at all the growth stages. A positive relationship was obtained between Na content in leaves and roots at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 10.71 + 0.28X$ ($r = 0.563$, $p<0.05$, $df = 11$)

Root: $Y = 8.79 + 0.27X$ ($r = 0.585$, $p<0.05$, $df = 11$)

Where Y is Na content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Sodium content in inflorescences did not increase significantly with increase in soil salinity. Sodium content in inflorescences was almost similar at 9 and 12-week growth stages.

K content in tissues

As the age of control as well as salt-stressed plants advanced, potassium content significantly increased ($p<0.01$) in leaves, stems and roots (Table 1). Increase in soil salinity caused a significant reduction in K content of leaves and stems ($p<0.05$) and roots ($p<0.01$) of control and salt-stressed plants. Potassium content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants K content was maximum in leaves and minimum in roots. There was a significant negative relationship between soil salinity and k content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 22.98 – 0.52X$ ($r = -0.626$, $p<0.05$, $df = 11$)

Stem: $Y = 21.48 – 0.52X$ ($r = -0.595$, $p<0.05$, $df = 11$)

Root: $Y = 20.48 – 0.52X$ ($r = -0.599$, $p<0.05$, $df = 11$)

Where Y is K content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Potassium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, K content in inflorescences was almost similar at 9 and 12-week growth stages.

K/Na ratio in tissues

There was no significant change in K/Na ratio of leaves, stems and roots with increase of age for control as well as salt-stressed plants (Table 1). The K/Na ratio significantly decreased ($p<0.01$) in leaves, stems and roots of plants as soil salinity increased. Consequently, K/Na ratio was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. A negative relationship was obtained between soil salinity and K/Na ratio in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 2.25 – 0.10X$ ($r = -0.585$, $p<0.05$, $df = 11$)

Stem: $Y = 2.17 – 0.09X$ ($r = -0.836$, $p<0.01$, $df = 11$)

Root: $Y = 2.38 – 0.11X$ ($r = -0.665$, $p<0.05$, $df = 11$)

Where Y is K/Na ratio of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant change in K/Na ratio in inflorescences with the increase in soil salinity. The K/Na ratio in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Nitrogen, Phosphorus, Calcium and Magnesium Content in Tissues

N content in tissues

As the age of control and salt-stressed plants increased, N content significantly increased ($p<0.01$) in leaves, stems and roots (Table 1). Increase in soil salinity significantly reduced ($p<0.01$) N content in tissues of salt-stressed plants. As a result, N content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dSm^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants N content was maximum in leaves and minimum in roots at all the growth stages. A negative relationship was obtained between N content in tissues at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 34.56 – 0.76X$ ($r = -0.911$, $p<0.01$, $df = 11$)

Stem: $Y = 33.54 – 0.78X$ ($r = -0.931$, $p<0.01$, $df = 11$)

Root: $Y = 32.54 – 0.78X$ ($r = -0.946$, $p<0.01$, $df = 11$)

Where Y is N content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Nitrogen content in inflorescences did not decrease significantly with increase in soil salinity. Nitrogen content in inflorescences was almost similar at 9 and 12-week growth stages.

P content in tissues

As the age of control as well as salt-stressed plants advanced, P content significantly increased in leaves ($p<0.01$), stems ($p<0.0$) and roots ($p<0.05$) (Table 1). In addition, P content significantly decreased in leaves and stems ($p<0.05$) with increase of salt concentration in soil. There was no significant decrease in P content in roots with increase of salt concentration in soil. Phosphorus content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants P content was maximum in leaves and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and P content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.16 – 0.11X$ ($r = -0.734$, $p<0.01$, $df = 11$)

Stem: $Y = 3.27 – 0.13X$ ($r = -0.669$, $p<0.01$, $df = 11$)

Where Y is P content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Phosphorus content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, P content in inflorescences was almost similar at 9 and 12-week growth stages.

Ca content in tissues

Calcium content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 1). Further, Ca content significantly decreased in leaves ($p<0.05$) and roots ($p<0.01$) with increase of salt

concentration in soil. There was no significant decrease in Ca content in stems with increase of salt concentration in soil. Consequently, Ca content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Ca content was maximum in stems and minimum in roots at all the growth stages. A significant negative relationship was found between soil salinity and Ca content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 8.75 – 0.18X$ ($r = -0.554$, $p<0.05$, $df = 11$)

Root: $Y = 6.92 – 0.24X$ ($r= -0.632$, $p<0.05$, $df = 11$)

Where Y is Ca content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Ca content in inflorescences with increase in soil salinity. Calcium content in inflorescences was almost similar at 9 and 12-week growth stages.

Mg content in tissues

Magnesium content significantly increased ($p<0.05$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 1). Increase in soil salinity caused a significant reduction in Mg content of leaves and roots ($p<0.05$) of control and salt-stressed plants. There was no significant decrease in Mg content in stems with increase of salt concentration in soil. Consequently, Mg content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Mg content was maximum in stems and minimum in roots at all the growth

stages. A significant negative relationship was obtained between soil salinity and Mg content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.52 – 0.17X$ ($r = -0.559$, $p<0.05$, $df = 11$)

Root: $Y = 3.59 – 0.14X$ ($r= -0.577$, $p<0.05$, $df = 11$)

Where Y is Mg content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Mg content in inflorescences with increase in soil salinity. Further, Mg content in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Zinc, Copper, Manganese and Iron Content in Tissues

Zn content in tissues

As the age of control as well as salt-stressed plants advanced, zinc content significantly increased ($p<0.01$) in leaves, stems and roots (Table 1). In addition, Zn content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Zinc content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Zn content was maximum in leaves and minimum in roots. There was a significant

negative relationship between soil salinity and Zn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 46.48 – 0.87X$ ($r = -0.827$, $p<0.01$, $df = 11$)

Stem: $Y = 44.19 – 0.96X$ ($r = -0.754$, $p<0.01$, $df = 11$)

Root: $Y = 36.57 – 0.86X$ ($r = -0.689$, $p<0.01$, $df = 11$)

Where Y is Zn content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

Zinc content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Zn content in inflorescences was almost similar at 9 and 12-week growth stages.

Cu content in tissues

As the age of control and salt-stressed plants increased, Cu content significantly increased in leaves ($p<0.05$), stems ($p<0.01$) and roots ($p<0.05$) (Table 1). In addition, Cu content significantly decreased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) with increase of salt concentration in soil. Copper content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 $dS\ m^{-1}$ salinity. Among the leaves, stems and roots of both control and salt-stressed plants Cu content was maximum in leaves and minimum in roots. A negative relationship was obtained between Cu content in tissues at 12-week growth stage and soil salinity according to the following expressions:

Leaf: $Y = 23.84 – 0.42X$ ($r = -0.562$, $p<0.05$, $df = 11$)

Stem: $Y = 22.27 – 0.39X$ ($r = -0.564$, $p<0.05$, $df = 11$)

Root: $Y = 17.73 – 0.39X$ ($r = -0.589$, $p<0.05$, $df = 11$)

Where Y is Cu content (μg g^{-1}) and X is salt concentration in soil (dS m^{-1}).

Copper content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Cu content in inflorescences was almost similar at 9 and 12-week growth stages.

Mn content in tissues

As the age of control and salt-stressed plants increased, Mn content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Table 1). Further, Mn content in tissues (leaves, stems and roots) significantly increased ($p<0.01$) with increase of salt concentration in soil. Manganese content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Mn content was maximum in roots and minimum in leaves. A positive relationship was obtained between Mn content in tissues at 12-week growth stage and soil salinity according to the following expressions:

Leaf: $Y = 47.99 + 1.33X$ ($r = 0.878$, $p<0.01$, $df = 11$)

Stem: $Y = 52.14 + 1.46X$ ($r = 0.928$, $p<0.01$, $df = 11$)

Root: $Y = 54.99 + 1.33X$ ($r = 0.912$, $p<0.01$, $df = 11$)

Where Y is Mn content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Manganese content in inflorescences did not increase significantly with increase in soil salinity. Manganese content in inflorescences was almost similar at 9 and 12-week growth stages.

Fe content in tissues

As the age of control as well as salt-stressed plants advanced, iron content significantly increased in leaves ($p<0.05$) stems and roots ($p<0.01$) (Table 1). Further, Fe content significantly decreased in leaves ($p<0.05$), stems and roots ($p<0.01$) with increase of salt concentration in soil. Iron content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Fe content was maximum in roots and minimum in leaves. There was a significant negative relationship between soil salinity and Fe content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 444.61 – 8.59X$ ($r = -0.557$, $p<0.05$, $df = 11$)

Stem: $Y = 537.00 – 9.19X$ ($r = -0.759$, $p<0.01$, $df = 11$)

Root: $Y = 677.90 – 11.30X$ ($r = -0.572$, $p<0.05$, $df = 11$)

Where Y is Fe content (µg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Iron content in inflorescences did not decrease significantly with increase in soil salinity. Iron content in inflorescences was almost similar at 9 and 12-week growth stages.

Table 1. Effect of soil salinity on nutrient content of tissues (leaf, stem, root and inflorescence) of *Pennisetum glaucum* variety **GHB 538** at different growth stages as indicated by mean ± SEM.

		3-week growth stage										
	Salinity ($dS\ m^{-1}$)	**N ($mg\ g^{-1}$)**	**P ($mg\ g^{-1}$)**	**K ($mg\ g^{-1}$)**	**Na ($mg\ g^{-1}$)**	**Ca ($mg\ g^{-1}$)**	**Mg ($mg\ g^{-1}$)**	**K/Na ratio**	**Zn ($\mu g\ g^{-1}$)**	**Cu ($\mu g\ g^{-1}$)**	**Mn ($\mu g\ g^{-1}$)**	**Fe ($\mu g\ g^{-1}$)**
Leaf	**0.3**	29±0.2	2.7±0.2	17.5±1.3	8±1.0	7.3±0.4	3±0.5	2.2±0.2	42±0.8	20.9±1.4	39±2.0	386±18.0
	3.9	27±0.3	2.3±0.3	16.5±1.4	8.7±0.7	6.5±0.4	2.6±1.0	1.9±0.2	39±0.7	19.8±1.0	42±1.5	360±17.7
	6	25±0.5	2±0.4	15±1.7	9.5±1.3	6±0.3	2.3±0.7	1.7±0.3	36.5±0.1	18.5±1.4	46±0.6	340±31.3
	7.9	23±0.6	1.7±0.5	13.5±1.4	10.1±0.8	5.4±0.2	1.9±0.3	1.3±0.1	34±1.3	17.3±1.4	50±1.5	312±32.0
Stem	**0.3**	28±0.4	2.1±0.2	16.8±1.6	6.5±1.0	8.3±0.7	4.5±0.6	2.7±0.5	40±1.7	18.5±1.3	46±1.5	459±19.9
	3.9	26±0.5	1.7±0.5	15.5±1.3	7.3±0.9	7.5±1.0	4±0.9	2.1±0.1	37±1.4	17.6±1.2	50±1.0	435±35.0
	6	24±0.8	1.4±0.3	14.3±1.9	8±1.2	6.8±0.6	3.5±0.5	1.9±0.5	34±1.7	16.5±1.0	54±0.5	410±10.9
	7.9	21±0.6	1.1±0.4	13±0.8	8.8±0.7	6±1.0	3±0.7	1.5±0.2	31±0.3	15.5±1.2	56.5±0.8	390±27.9
Root	**0.3**	27±0.9	1.9±0.1	15.5±1.3	6±1.0	5.2±0.7	2.1±0.5	2.7±0.4	30.5±1.3	15±1.0	50±1.0	583±23.7
	3.9	24.5±0.7	1.5±0.3	14.5±1.4	6.6±0.8	4.4±0.3	1.7±1.0	2.2±0.1	27.5±1.1	13.6±1.3	53±0.6	555±42.7
	6	22.5±0.5	1.3±0.5	13±1.2	7.5±1.0	3.7±0.2	1.4±0.5	1.8±0.2	25.5±1.4	12.5±1.3	56±0.7	525±12.7
	7.9	20±0.6	1.1±0.4	11.5±0.5	8.2±0.6	3.1±0.2	1.1±0.5	1.4±0.1	23±1.4	11.5±1.2	58.9±1.6	500±39.0

Table 1. (Continued)

		6-week growth stage										
	Salinity ($dS\ m^{-1}$)	**N ($mg\ g^{-1}$)**	**P ($mg\ g^{-1}$)**	**K ($mg\ g^{-1}$)**	**Na ($mg\ g^{-1}$)**	**Ca ($mg\ g^{-1}$)**	**Mg ($mg\ g^{-1}$)**	**K/Na ratio**	**Zn ($\mu g\ g^{-1}$)**	**Cu ($\mu g\ g^{-1}$)**	**Mn ($\mu g\ g^{-1}$)**	**Fe ($\mu g\ g^{-1}$)**
Leaf	**0.3**	32±0.7	3.2±0.2	19±1.0	9±1.2	7.8±0.9	3.5±0.6	2.2±0.4	43.5±0.9	22±0.9	43±2.5	410±7.6
	3.9	30±0.3	2.8±0.4	18±1.7	9.7±1.1	7.1±0.8	3.1±1.1	1.9±0.1	41±1.2	20.8±1.1	46±0.6	382±29.3
	6	28±1.0	2.5±0.5	16.7±1.4	10.4±0.9	6.5±0.6	2.8±0.5	1.6±0.1	39.3±1.0	19.8±0.1	50±1.5	358±44.6
	7.9	26±0.9	2.2±0.4	15.5±1.3	11±1.0	6±0.9	2.4±0.9	1.4±0.2	37±1.0	18.5±1.2	53±2.3	337±27.9
Stem	**0.3**	31±0.7	2.5±0.3	18.5±1.8	7.8±1.0	8.8±0.6	4.9±0.6	2.5±0.5	41.5±1.4	19.5±1.1	49±1.2	493±17.1
	3.9	29±0.2	2.1±0.2	17.5±0.8	8.5±1.0	8.3±0.7	4.5±0.7	2.1±0.4	38.5±1.5	18.5±1.3	53±1.1	467±22.1
	6	27±0.8	1.8±0.4	16±1.2	9.3±0.5	7.6±0.9	4±0.8	1.7±0.2	36±1.6	17.9±1.0	57±0.6	440±19.8
	7.9	25±0.4	1.5±0.3	14.5±1.3	10±0.8	6.8±0.4	3.5±0.6	1.5±0.2	33.5±1.8	17±0.8	60±1.0	418±4.0
Root	**0.3**	29.5±0.5	2.2±0.3	17.5±1.3	7±1.0	5.8±0.4	2.6±0.8	2.7±0.7	32.5±1.3	16.2±1.2	53±1.2	615±9.1
	3.9	27±0.9	1.8±0.5	16±1.7	7.5±0.8	5±0.3	2.2±0.6	2.2±0.3	30±2.1	14.8±1.6	56±0.7	584±22.7
	6	25±0.2	1.6±0.2	14.5±1.3	8.3±1.2	4.4±0.2	1.9±1.1	1.8±0.1	27.5±1.1	13.8±1.1	59±1.5	560±26.3
	7.9	23±0.7	1.4±0.3	13±1.0	9±1.2	3.7±0.4	1.6±0.7	1.5±0.2	25.5±1.3	12.9±1.4	62±1.7	532±61.1

Table 1. (Continued)

		9-week growth stage										
	Salinity ($dS\ m^{-1}$)	**N ($mg\ g^{-1}$)**	**P ($mg\ g^{-1}$)**	**K ($mg\ g^{-1}$)**	**Na ($mg\ g^{-1}$)**	**Ca ($mg\ g^{-1}$)**	**Mg ($mg\ g^{-1}$)**	**K/Na ratio**	**Zn ($\mu g\ g^{-1}$)**	**Cu ($\mu g\ g^{-1}$)**	**Mn ($\mu g\ g^{-1}$)**	**Fe ($\mu g\ g^{-1}$)**
Leaf	**0.3**	33±0.2	3.7±0.4	21±0.6	10±1.2	8.2±0.7	3.9±0.7	2.1±0.2	44.5±1.0	22.7±1.0	46±0.6	425±8.5
	3.9	31±0.6	3.3±0.2	19.8±2.0	10.7±0.7	7.6±0.5	3.5±1.1	1.9±0.3	42±1.0	21.5±0.9	49±0.7	399±23.0
	6	29.5±0.7	3±0.1	18.5±1.3	11.5±0.9	7±0.9	3.2±0.7	1.6±0.1	40±0.9	20.6±0.9	53±2.3	375±48.8
	7.9	27.5±0.6	2.7±0.5	17±1.2	12±1.2	6.4±0.6	2.9±0.8	1.4±0.1	38±1.0	19.3±1.4	56±0.8	352±39.8
Stem	**0.3**	32±0.5	2.9±0.3	20±1.2	8.8±0.6	9.3±0.6	5.2±0.7	2.3±0.3	42.5±1.6	20.8±1.0	51±1.5	510±10.3
	3.9	30±0.6	2.5±0.2	19±1.2	9.7±0.9	8.7±0.8	4.8±0.4	2.0±0.2	40±2.1	19.9±1.3	55±1.5	485±10.4
	6	28±0.6	2.2±0.5	17.5±0.8	10.5±0.9	8.1±0.7	4.4±0.6	1.7±0.1	37.3±1.8	19±1.0	59±1.0	463±25.9
	7.9	26±0.5	1.9±0.3	16±1.5	11.2±1.0	7.3±0.7	3.9±0.7	1.5±0.3	35±1.3	17.9±1.0	62±0.6	440±19.8
Root	**0.3**	31±0.6	2.5±0.3	19.3±1.9	8±0.6	6.3±0.6	3.1±0.6	2.4±0.3	34.8±1.4	17±0.9	55±1.2	640±25.1
	3.9	29±0.2	2.1±0.5	18±1.0	8.5±1.0	5.7±0.2	2.7±1.0	2.2±0.4	32.5±2.5	15.9±1.1	58±0.6	612±6.4
	6	27±0.6	1.9±0.2	16.5±1.6	9.3±0.9	5±0.6	2.4±0.8	1.8±0.3	30±1.2	14.8±1.3	61±0.7	589±17.8
	7.9	25±0.5	1.7±0.2	15±1.5	9.9±0.7	4.3±0.7	2±0.7	1.5±0.2	27.5±1.4	13.8±1.0	64±1.0	558±27.1
Inflor.	**0.3**	33.2±0.3	3.8±0.1	21.2±0.6	10.3±0.8	8.3±0.2	4±0.9	2.1±0.2	44.8±0.9	22.9±1.4	47±0.6	430±26.9
	3.9	32.6±0.4	3.5±0.3	20.9±0.1	10.8±0.9	8±0.1	3.7±0.5	2.0±0.2	44.5±1.0	22.5±1.7	49±1.0	395±19.3
	6	31.2±0.7	3.2±0.3	20.5±0.4	11.3±1.1	7.8±0.1	3.5±0.6	1.8±0.1	44±1.3	22±0.9	50±1.5	380±10.5
	7.9	30.8±1.1	3±0.2	20.3±0.6	11.6±0.9	7.5±0.3	3±0.5	1.8±0.2	43.8±1.0	21.8±1.1	51±0.7	370±8.4

Table 1. (Continued)

	12-week growth stage											
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	34±0.3	4.1±0.2	22.5±1.8	10.9±1.5	8.6±0.8	4.5±1.0	2.2±0.5	46±1.3	23.5±1.0	49±0.7	440±15.9
	3.9	32±0.7	3.8±0.1	21.5±0.9	11.6±0.9	8.2±0.7	3.8±0.6	1.9±0.2	43.5±1.3	22.5±1.7	52±2.5	415±7.0
	6	30.5±0.5	3.5±0.3	20±1.2	12.5±0.8	7.8±0.6	3.5±0.5	1.6±0.1	41.3±0.9	21.5±1.3	56±0.6	393±30.9
	7.9	28±0.7	3.3±0.2	18.5±1.0	13±1.2	7.2±0.7	3.2±0.6	1.4±0.1	39.4±1.2	20.2±1.1	59±0.5	375±46.0
Stem	**0.3**	33±0.6	3.2±0.3	21±1.7	10±0.9	10±0.6	5.5±0.8	2.1±0.1	43.5±1.7	22±1.1	53±1.2	530±10.3
	3.9	31±0.5	2.8±0.4	20±1.0	10.8±0.9	9.3±0.4	5.2±0.9	1.9±0.1	41±1.3	21±0.9	57±1.2	508±9.0
	6	29±0.6	2.5±0.3	18.5±1.6	11.7±0.8	8.6±0.6	4.8±0.6	1.6±0.2	38.8±1.5	20±1.3	61±1.1	485±10.4
	7.9	27±0.5	2.2±0.1	17±1.0	12.5±1.3	7.8±0.6	4.3±0.6	1.4±0.1	36±2.0	19±1.1	64±1.0	459±25.2
Root	**0.3**	32±0.5	2.7±0.4	20±1.7	9±1.0	6.7±0.4	3.5±0.8	2.3±0.4	36±1.3	17.5±1.2	56±1.0	670±54.2
	3.9	30±0.2	2.3±0.3	19±1.5	9.6±0.9	6.2±0.6	3.1±0.7	2.0±0.1	33.8±2.1	16.4±1.4	59±1.5	641±24.4
	6	28±0.6	2.1±0.4	17.5±0.9	10.4±1.1	5.6±0.2	2.8±1.0	1.7±0.2	31.5±1.5	15.5±1.0	63±0.6	613±5.5
	7.9	26±0.5	1.9±0.6	16±1.2	11±0.6	4.8±0.9	2.4±1.0	1.5±0.1	29.5±2.0	14.5±1.4	66±1.0	583±23.7
Inflor.	**0.3**	33.7±0.5	4±0.2	21.5±0.3	10.5±0.6	8.5±0.3	4.3±0.6	2.1±0.1	45±0.8	23.2±0.7	48±0.6	435±22.5
	3.9	32.8±0.4	3.7±0.2	21.3±0.5	11.2±1.1	8.2±0.3	4±0.8	1.9±0.2	44.7±0.9	22.8±1.5	50±1.5	400±18.2
	6	31.7±0.6	3.5±0.3	20.8±0.2	11.5±1.1	8±0.1	3.7±0.5	1.8±0.1	44.3±0.4	22.4±1.7	52±1.2	390±22.7
	7.9	30.9±1.0	3.2±0.3	20.5±0.4	11.7±0.9	7.8±0.1	3.5±0.6	1.8±0.1	44±1.3	22±0.9	53±1.2	385±8.9

Variety GHB 558

Effect of Salinity on Sodium and Potassium Content and K/Na Ratio in Tissues.

Na content in tissues

Sodium content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 2). Moreover, Na content in leaves significantly increased ($p<0.05$) with increase of salt concentration in soil. There was no significant increase in stems and roots with increase of salt concentration in soil. Sodium content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity and minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Na content was maximum in leaves and minimum in roots at all the growth stages. There was a positive relationship between Na content in leaves at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 9.63 + 0.26X$ ($r = 0.582$, $p<0.05$, $df = 11$)

Where Y is Na content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant increase in Na content in inflorescences with the increase in soil salinity. Sodium content in inflorescences was almost similar at 9 and 12-week growth stages.

K content in tissues

Potassium content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 2). In addition, K content significantly decreased in leaves ($p<0.05$), stems ($p<0.01$) and roots ($p<0.05$) with increase of salt concentration in soil. Consequently, K content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants K content was maximum in leaves and minimum in roots. A significant negative relationship was obtained between soil salinity and K content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 24.92 – 0.73X$ ($r = -0.768$, $p<0.01$, $df = 11$)

Stem: $Y = 23.07 – 0.59X$ ($r = -0.664$, $p<0.01$, $df = 11$)

Root: $Y = 21.52 – 0.64X$ ($r = -0.710$, $p<0.01$, $df = 11$)

Where Y is K content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in K content in inflorescences with increase in soil salinity. Moreover, K content in inflorescences was almost similar at 9 and 12-week growth stages.

K/Na ratio in tissues

The K/Na ratio in leaves, stems and roots did not change significantly as the age of control and salt stressed plants increased (Table 2). Increase in soil salinity caused a significant reduction ($p<0.01$) in K/Na ratio of leaves, stems and roots of control and salt-stressed plants. The K/Na ratio was maximum in tissues of control plants,

whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. There was a negative relationship between soil salinity and K/Na ratio in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 2.59 – 0.12X$ ($r = -0.684$, $p<0.01$, $df = 11$)

Stem: $Y = 2.59 – 0.11X$ ($r = -0.712$, $p<0.01$, $df = 11$)

Root: $Y = 3.35 – 0.22X$ ($r = -0.726$, $p<0.01$, $df = 11$)

Where Y is K/Na ratio of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant change in K/Na ratio in inflorescences with the increase in soil salinity. The K/Na ratio in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Nitrogen, Phosphorus, Calcium and Magnesium Content in Tissues

N content in tissues

Nitrogen content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 2). Moreover, N content in tissues of plants significantly decreased ($p<0.01$) with increase of salt concentration in soil. Nitrogen content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants N content was maximum in leaves and minimum in roots at all the growth stages. There was a

negative relationship between soil salinity and N content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 36.04 – 0.78X$ ($r = -0.904$, $p<0.01$, $df = 11$)

Stem: $Y = 30.52 – 0.81X$ ($r = -0.912$, $p<0.01$, $df = 11$)

Root: $Y = 26.77 – 0.86X$ ($r = -0.914$, $p<0.01$, $df = 11$)

Where Y is N content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in N content in inflorescences with the increase in soil salinity. Nitrogen content in inflorescences was almost similar at 9 and 12-week growth stages.

P content in tissues

Phosphorus content significantly increased in leaves ($p<0.01$), stems ($p<0.01$) and roots ($p<0.05$) as the age of control and salt-stressed plants increased (Table 2). Increase in soil salinity significantly reduced P content in leaves and stems ($p<0.05$). There was no significant decrease in P content in roots with increase of salt concentration in soil. Consequently, P content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants P content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and P content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.97 – 0.13X$ ($r = -0.585$, $p<0.05$, $df = 11$)

Stem: $Y = 4.39 – 0.15X$ ($r= -0.553$, $p<0.05$, $df = 11$)

Where Y is P content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in P content in inflorescences with increase in soil salinity. Phosphorus content in inflorescences was almost similar at 9 and 12-week growth stages.

Ca content in tissues

As the age of control as well as salt-stressed plants advanced, Ca content significantly increased ($p<0.01$) in leaves, stems and roots (Table 2). In addition, Ca content significantly decreased in leaves ($p<0.05$) and roots ($p<0.01$) with increase of salt concentration in soil. There was no significant decrease in Ca content in stems with increase of salt concentration in soil. Calcium content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Ca content was maximum in stems and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and Ca content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 10.75 – 0.21X$ ($r = -0.587$, $p<0.05$, $df = 11$)

Root: $Y = 7.95 – 0.25X$ ($r = -0.654$, $p<0.05$, $df = 11$)

Where Y is Ca content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Calcium content in inflorescences did not decrease significantly with increase in soil salinity. Calcium content in inflorescences was almost similar at 9 and 12-week growth stages.

Mg content in tissues

As the age of control as well as salt-stressed plants advanced, Mg content significantly increased in leaves ($p<0.01$), stems and roots ($p<0.05$) (Table 2). In addition, Mg content significantly decreased in leaves and roots ($p<0.05$) with increase of salt concentration in soil. There was no significant decrease in Mg content in stems with increase of salt concentration in soil. Magnesium content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Mg content was maximum in stems and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and Mg content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 5.44 – 0.19X$ ($r = -0.561$, $p<0.05$, $df = 11$)

Root: $Y = 3.69 – 0.17X$ ($r = -0.581$, $p<0.05$, $df = 11$)

Where Y is Mg content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Magnesium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Mg content in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Zinc, Copper, Manganese and Iron Content in Tissues

Zn content in tissues

Zinc content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 2). Further, Zn content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Consequently, Zn content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Zn content was maximum in leaves and minimum in roots. A significant negative relationship was found between soil salinity and Zn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 53.03 – 0.79X$ ($r = -0.789$, $p<0.01$, $df = 11$)

Stem: $Y = 50.08 – 0.90X$ ($r = -0.835$, $p<0.01$, $df = 11$)

Root: $Y = 35.67 – 0.98X$ ($r = -0.816$, $p<0.01$, $df = 11$)

Where Y is Zn content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Zn content in inflorescences with increase in soil salinity. Zinc content in inflorescences was almost similar at 9 and 12-week growth stages.

Cu content in tissues

Copper content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 2). Increase in soil salinity significantly reduced ($p<0.01$), Cu content in leaves, stems and roots. Consequently, Cu content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Cu content was maximum in leaves and minimum in roots. A significant negative relationship was found between soil salinity and Cu content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 36.23 – 0.59X$ ($r = -0.752$, $p<0.01$, $df = 11$)

Stem: $Y = 26.45 – 0.61X$ ($r = -0.573$, $p<0.05$, $df = 11$)

Root: $Y = 23.90 – 0.59X$ ($r = -0.662$, $p<0.05$, $df = 11$)

Where Y is Cu content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Cu content in inflorescences with increase in soil salinity. Further, Cu content in inflorescences was almost similar at 9 and 12-week growth stages.

Mn content in tissues

Manganese content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 2). In addition, Mn content significantly increased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Consequently, Mn content was maximum in

tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Mn content was maximum in roots and minimum in leaves. There was a positive relationship between soil salinity and Mn content in leaves at 12-week growth stage according to the following expressions:

Leaf: $Y = 50.18 + 1.17X$ ($r = 0.867$, $p<0.01$, $df = 11$)

Stem: $Y = 53.72 + 1.72X$ ($r = 0.937$, $p<0.01$, $df = 11$)

Root: $Y = 58.72 + 1.72X$ ($r = 0.943$, $p<0.01$, $df = 11$)

Where Y is Mn content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant increase in Mn content in inflorescences with the increase in soil salinity. Moreover, Mn content in inflorescences was almost similar at 9 and 12-week growth stages.

Fe content in tissues

Iron content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) as the age of control and salt-stressed plants increased (Table 2). Increase in soil salinity significantly reduced Fe content in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$). Consequently, Fe content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Fe content was maximum in roots and minimum in leaves. A significant negative relationship was found between soil salinity and Fe content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 494.21 – 10.17X$ ($r = -0.576$, $p<0.05$, $df = 11$)

Stem: $Y = 541.60 – 8.15X$ ($r = -0.577$, $p<0.05$, $df = 11$)

Root: $Y = 563.00 – 10.45X$ ($r = -0.777$, $p<0.01$, $df = 11$)

Where Y is Fe content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

There was no significant decrease in Fe content in inflorescences with increase in soil salinity. Moreover, Fe content in inflorescences was almost similar at 9 and 12-week growth stages.

Table 2. Effect of soil salinity on nutrient content of tissues (leaf, stem, root and inflorescence of *Pennisetum glaucum* variety **GHB 558** at different growth stages as indicated by mean ± SEM.

		3-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	30.5±0.3	4±0.3	17.5±1.8	7±0.1	8.8±1.0	3.9±0.8	2.5±0.3	47±1.3	31.5±1.2	42±1.2	411±7.8
	3.9	29±0.6	3.6±0.2	16±1.5	7.6±0.7	8.1±0.7	3.5±0.5	2.1±0.3	44.5±1.7	29.5±0.9	46±1.0	384±19.7
	6	27±0.9	3.3±0.2	14±1.7	8.3±1.2	7.5±0.5	3±1.0	1.8±0.4	42.5±1.3	27.5±0.9	50±1.2	355±16.3
	7.9	25±0.6	3±0.3	12±1.0	9±0.5	7±0.8	2.6±0.8	1.3±0.1	40.5±1.1	25.5±1.5	53±1.0	330±15.0
Stem	**0.3**	26±0.5	3.5±0.5	16±1.5	6.5±0.8	9.5±0.9	5.3±0.9	2.5±0.3	43±0.9	22±1.3	48±2.1	476±27.7
	3.9	22.8±0.5	3±0.2	14.5±1.8	7.3±0.7	8.5±0.9	4.8±0.6	2.1±0.5	41±1.1	20±1.0	52±2.6	450±34.8
	6	20±0.3	2.6±0.3	12.5±1.3	8±0.8	7.8±1.1	4.3±0.4	1.6±0.3	38.5±0.9	18.5±1.5	57±2.1	428±23.1
	7.9	19±0.6	2.3±0.5	11±0.6	8.7±1.0	7±1.0	3.8±0.7	1.3±0.2	35.5±1.0	17±2.4	60±1.7	400±48.5
Root	**0.3**	22±0.8	3.1±0.4	14.5±1.3	5.5±0.8	6.2±0.7	2.5±0.4	2.7±0.2	28.5±1.1	19.5±1.3	51±0.5	499±11.5
	3.9	18±0.2	2.7±0.5	13.5±1.6	6.3±0.9	5.5±0.5	2.1±0.7	2.2±0.1	26±1.1	18±1.7	55±1.2	473±24.3
	6	15.5±0.7	2.3±0.3	11.8±1.0	7±0.5	4.8±0.2	1.7±0.5	1.7±0.1	24±1.4	16.5±1.6	60±1.0	453±13.2
	7.9	13.5±0.9	2±0.1	10.8±1.6	7.7±0.9	4.3±0.6	1.3±0.5	1.4±0.2	22±1.0	15±1.1	64±2.3	425±23.7

Table 2. (Continued)

	6-week growth period											
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	33.5±0.3	4.4±0.2	20±1.0	7.9±0.7	9.5±1.0	4.4±0.7	2.6±0.1	50±1.0	33.5±0.8	46±1.0	442±24.9
	3.9	31±0.6	4±0.3	18.5±1.3	8.5±1.3	9±0.9	4±0.7	2.3±0.4	47.5±1.4	31.5±1.0	49±1.0	411±7.8
	6	29.5±0.3	3.7±0.5	16.5±1.3	9.3±1.0	8.5±1.0	3.5±1.4	1.8±0.3	45.5±1.4	30±1.2	53±1.5	385±19.3
	7.9	27.5±0.4	3.4±0.2	15±1.7	10±0.8	8±0.9	3±0.6	1.5±0.2	43±0.8	28.5±1.5	56±1.0	359±12.3
Stem	**0.3**	28.5±0.8	3.8±0.5	18.5±1.4	7.5±1.3	10.3±0.9	5.7±0.6	2.7±0.6	46.5±1.3	23.5±1.2	51±1.5	493±33.0
	3.9	25.5±0.6	3.4±0.5	17±1.2	8.2±0.9	9.5±1.3	5.2±0.6	2.1±0.1	44±1.4	21.5±1.5	55±1.5	468±25.2
	6	23±0.3	3±0.3	15.3±1.8	8.8±0.6	8.6±0.8	4.8±0.9	1.8±0.3	41.5±1.0	20±1.1	59±1.7	447±12.4
	7.9	21.5±0.3	2.7±0.4	14±1.5	9.5±0.8	7.8±0.7	4.4±0.6	1.5±0.1	39±1.0	18.5±2.1	63±1.7	422±18.0
Root	**0.3**	24±0.8	3.4±0.3	17±1.2	6±1.2	6.8±0.4	3±0.7	3.1±0.8	31.5±1.4	21±1.6	54±1.0	520±8.7
	3.9	20.5±0.3	3±0.3	15.5±1.3	6.8±0.9	6.2±0.2	2.5±0.7	2.3±0.2	29±1.0	19.3±1.0	58±1.0	496±13.5
	6	18.5±0.8	2.6±0.6	14±1.5	7.6±0.8	5.6±0.2	2.1±0.8	1.9±0.4	27.3±1.4	17.5±1.4	63±0.5	469±10.5
	7.9	16±0.7	2.3±0.2	12.5±1.4	8.5±0.8	5.1±0.5	1.7±0.5	1.5±0.3	25±1.1	16.5±1.6	67±1.2	448±13.0

Table 2. (Continued)

		9-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	35±0.7	4.7±0.5	22±1.5	8.8±0.8	10.1±1.0	4.8±1.5	2.6±0.4	51.5±1.3	34.5±1.5	49±1.0	468±50.7
	3.9	32.5±0.3	4.3±0.5	20.5±1.8	9.5±1.0	9.5±0.9	4.4±0.5	2.2±0.2	48.8±1.0	33±1.7	52±1.0	436±19.0
	6	30.5±0.3	4±0.1	18.6±1.8	10.3±0.9	9±0.8	3.9±0.8	1.7±0.4	47±1.2	31.5±0.8	55±1.2	410±7.0
	7.9	28.5±0.5	3.7±0.2	17±1.2	11±1.2	8.4±0.7	3.4±0.7	1.6±0.1	45±1.2	30±1.2	58±1.2	383±20.1
Stem	**0.3**	29.5±0.8	4.1±0.4	19.8±1.5	8.3±0.9	11±1.0	6.2±0.9	2.4±0.1	48.5±0.9	24.5±1.4	53±2.3	514±12.1
	3.9	27±0.6	3.7±0.2	18.5±1.3	8.9±0.5	10.4±0.8	5.7±0.5	2.1±0.1	46±1.3	23±1.4	57±1.0	489±28.0
	6	24.5±0.7	3.3±0.2	17±1.0	9.7±0.9	9.7±1.2	5.2±0.6	1.8±0.2	43.5±1.1	21.5±2.1	61±1.0	472±36.5
	7.9	23±0.4	3±0.5	15.5±1.8	10.2±1.0	9±1.3	4.8±0.4	1.5±0.1	41.5±1.0	20±1.1	65±1.0	449±14.2
Root	**0.3**	26±0.9	3.6±0.5	19±1.5	6.5±1.3	7.3±0.6	3.3±0.6	3.2±0.7	34±1.3	22.5±1.1	57±0.5	539±11.5
	3.9	22.5±0.3	3.2±0.2	17.5±1.0	7.4±0.7	6.7±0.4	2.9±0.9	2.4±0.4	31±1.1	20.5±1.3	61±1.2	514±5.3
	6	20.5±0.6	2.8±0.5	16±2.1	8.3±0.7	6.2±0.4	2.5±0.7	1.9±0.1	29±1.3	19±1.3	66±1.2	485±5.6
	7.9	18.5±0.3	2.5±0.4	14.5±1.3	9.3±0.7	5.6±0.5	2±0.8	1.6±0.2	26.5±1.3	17.5±1.4	70±1.5	463±8.7
Inflor.	**0.3**	35.3±0.6	4.8±0.1	22.2±0.6	8.9±0.5	10.3±0.9	4.9±0.3	2.5±0.2	51.8±1.0	34.8±0.9	50±1.0	470±21.7
	3.9	34.8±0.3	4.5±0.3	21.9±0.1	9.2±1.1	10±0.8	4.5±0.6	2.4±0.3	51.5±1.3	34.5±1.0	51±0.6	467±25.7
	6	32.8±1.0	4±0.1	21.5±0.4	9.5±0.8	9.8±0.6	4±0.7	2.3±0.2	51.1±0.4	34±1.2	52±2.1	460±23.9
	7.9	33.0±0.5	3.8±0.1	21.3±0.4	9.7±0.9	9.5±0.9	3.8±0.6	2.2±0.2	50.9±0.8	33.7±0.9	54±0.6	454±44.2

Table 2. (Continued)

		12-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	35.5±0.5	4.9±0.2	24.5±1.3	9.8±0.6	10.6±0.6	5.3±0.6	2.5±0.3	52.5±1.0	35.8±0.6	51±1.5	489±45.9
	3.9	33.5±0.4	4.5±0.5	22.5±0.8	10.5±1.3	10.1±0.8	4.8±0.8	2.2±0.2	50.5±1.2	34.3±1.5	54±1.5	458±55.7
	6	31.5±0.8	4.2±0.4	20.5±1.0	11.2±0.9	9.6±0.7	4.3±0.5	1.7±0.2	48.3±1.3	32.8±1.1	57±1.0	435±19.3
	7.9	29.5±0.8	3.9±0.2	19±1.5	11.8±0.9	9±1.0	3.8±0.6	1.7±0.3	46.5±1.3	31.2±0.6	60±1.0	411±6.1
Stem	**0.3**	30±0.6	4.3±0.2	22.5±1.0	9±0.8	11.3±1.1	6.6±1.5	2.5±0.2	49.5±1.1	26±1.1	55±1.2	537±11.1
	3.9	28±0.8	3.9±0.4	21.5±1.0	9.7±0.6	10.8±0.7	6.1±1.5	2.2±0.1	47±1.3	24.5±2.5	59±1.5	512±11.5
	6	25.5±0.3	3.5±0.7	19.5±1.3	10.5±1.0	10.2±1.0	5.5±0.7	1.9±0.3	45±0.4	23±1.4	64±1.0	497±36.1
	7.9	24±0.9	3.2±0.5	18±1.7	11±0.8	9.5±1.2	5.1±0.5	1.7±0.3	42.5±1.5	21.3±1.5	68±0.5	473±36.2
Root	**0.3**	26.5±0.9	3.8±0.2	21±1.0	7±1.3	7.8±0.6	3.6±0.5	3.3±0.7	35±1.2	23.5±1.3	60±1.5	557±19.2
	3.9	23.5±0.3	3.4±0.4	19.5±0.9	8±1.2	7.1±0.9	3.1±0.7	2.5±0.4	32.5±1.5	22±1.4	64±1.0	528±15.9
	6	21.5±0.8	2.9±0.2	18±1.7	9±1.0	6.5±0.3	2.8±0.6	2.0±0.2	30±1.7	20.5±1.3	69±0.6	500±14.0
	7.9	20±0.7	2.6±0.2	16±1.2	10±1.1	5.9±0.4	2.3±0.6	1.6±0.1	27.5±1.0	19±1.3	73±1.2	478±17.3
Inflor.	**0.3**	35.7±0.6	4.9±0.2	22.5±0.3	9±1.0	10.5±0.8	5.1±0.5	2.6±0.3	52±1.0	35±1.6	51±1.0	478±20.4
	3.9	34.3±0.5	4.7±0.2	22±0.1	9.5±0.8	10.2±0.7	4.8±0.4	2.3±0.2	51.7±1.0	34.7±1.0	53±1.2	471±21.7
	6	33.5±0.5	4.3±0.2	21.7±0.2	9.6±0.8	10±0.8	4.4±0.6	2.3±0.2	51.3±0.3	34.3±1.5	54±0.6	465±19.3
	7.9	33.2±0.6	4±0.1	21.5±0.4	9.8±0.9	9.7±0.5	4±0.7	2.2±0.2	51.1±0.4	34±1.2	55±1.0	450±43.0

Variety GHB 577

Effect of Salinity on Sodium and Potassium Content and K/Na Ratio in Tissues.

Na content in tissues

As the age of control and salt-stressed plants increased, sodium content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Table 3). In addition, Na content in leaves significantly increased ($p<0.05$) with increase of salt concentration in soil. There was no significant increase in stems and roots with increase of salt concentration in soil. Sodium content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Na content was maximum in leaves and minimum in roots. A positive relationship was found between Na content in leaves at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 10.85 + 0.31X$ ($r = 0.577$, $p<0.05$, $df = 11$)

Where Y is Na content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Sodium content in inflorescences did not increase significantly with increase in soil salinity. Sodium content in inflorescences was almost similar at 9 and 12-week growth stages.

K content in tissues

As the age of control as well as salt-stressed plants advanced, potassium content significantly increased ($p<0.01$) in leaves, stems and roots (Table 3). Moreover, increase in soil salinity significantly reduced ($p<0.05$) K content in leaves, stems and roots. As a result, K content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants K content was maximum in leaves and minimum in roots. There was a significant negative relationship between soil salinity and K content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 21.90 – 0.59X$ ($r = -0.658$, $p<0.05$, $df = 11$)

Stem: $Y = 18.81 – 0.39X$ ($r = -0.562$, $p<0.05$, $df = 11$)

Root: $Y = 19.92 – 0.73X$ ($r = -0.724$, $p<0.01$, $df = 11$)

Where Y is K content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Potassium content in inflorescences did not decrease with increase in soil salinity. Moreover, K content in inflorescences was almost similar at 9 and 12-week growth stages.

K/Na ratio in tissues

The K/Na ratio significantly increased in leaves and stems ($p<0.05$) with the increase in age of control as well as salt-stressed plants, whereas it did not significantly change in roots (Table 3). Moreover, increase in soil salinity significantly reduced ($p<0.01$) the K/Na ratio in leaves, stems and roots. As a result,

the K/Na ratio was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. There was a significant negative relationship between soil salinity and K/Na ratio in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 2.00 - 0.09X$ ($r = -0.760$, $p<0.01$, $df = 11$)

Stem: $Y = 1.98 - 0.08X$ ($r = -0.715$, $p<0.001$, $df = 11$)

Root: $Y = 2.85 - 0.17$ ($r= -0.687$, $p<0.01$, $df = 11$)

Where Y is K/Na ratio of tissues and X is salt concentration in soil (dS m^{-1}).

The K/Na ratio in inflorescences did not change significantly in respect to increase in age and increase in soil salinity.

Effect of Salinity on Nitrogen, Phosphorus, Calcium and Magnesium Content in Tissues

N content in tissues

As the age of control and salt-stressed plants increased, N content significantly increased ($p<0.01$) in leaves, stems and roots (Table 3). In addition, N content in tissues (leaves, stems and roots) significantly decreased ($p<0.01$) with increase of salt concentration in soil. Consequently, N content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity.

Among the leaves, stems and roots of both control and salt-stressed plants N content was maximum in leaves and minimum in roots at all the growth stages. A negative relationship was found between N content in tissues at 12-week growth stage and soil salinity according to the following expressions:

Leaf: $Y = 35.32 – 0.85X$ ($r = -0.928$, $p<0.01$, $df = 11$)

Stem: $Y = 32.18 – 0.79X$ ($r = -0.917$, $p<0.01$, $df = 11$)

Root: $Y = 29.16 – 0.64X$ ($r = -0.885$, $p<0.01$, $df = 11$)

Where Y is N content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Nitrogen content in inflorescences did not decrease significantly with increase in soil salinity. Nitrogen content in inflorescences was almost similar at 9 and 12-week growth stages.

P content in tissues

As the age of control as well as salt-stressed plants advanced, P content significantly increased in leaves ($p<0.05$), stems ($p<0.01$) and roots ($p<0.05$) (Table 3). Increase in soil salinity significantly reduced P content in leaves and stems ($p<0.05$). There was no significant decrease in P content in roots with increase of salt concentration in soil. Phosphorus content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants P content was maximum in leaves and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and P content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.39 – 0.15X$ ($r = -0.758$, $p<0.01$, $df = 11$)

Stem: $Y = 3.88 – 0.12X$ ($r = -0.577$, $p<0.01$, $df = 11$)

Where Y is P content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Phosphorus content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, P content in inflorescences was almost similar at 9 and 12-week growth stages.

Ca content in tissues

Calcium content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 3). Increase in soil salinity caused a significant reduction in Ca content of leaves ($p<0.05$) and roots ($p<0.01$) of control and salt-stressed plants. There was no significant decrease in Ca content in stems with increase of salt concentration in soil. Consequently, Ca content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Ca content was maximum in stems and minimum in roots at all the growth stages. A significant negative relationship was obtained between soil salinity and Ca content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 9.23 – 0.29X$ ($r = -0.668$, $p<0.05$, $df = 11$)

Root: $Y = 6.51 – 0.22X$ ($r= -0.569$, $p<0.05$, $df = 11$)

Where Y is Ca content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Ca content in inflorescences with increase in soil salinity. Further, Ca content in inflorescences was almost similar at 9 and 12-week growth stages.

Mg content in tissues

Magnesium content significantly increased in leaves ($p<0.01$), stems and roots ($p<0.05$) as the age of control and salt-stressed plants increased (Table 3). Further, Mg content significantly decreased in leaves and roots ($p<0.05$) with increase of salt concentration in soil. There was no significant decrease in Mg content in stems with increase of salt concentration in soil. Consequently, Mg content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Mg content was maximum in stems and minimum in roots at all the growth stages. A significant negative relationship was found between soil salinity and Mg content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.90 – 0.13X$ ($r = -0.601$, $p<0.05$, $df = 11$)

Root: $Y = 3.99 – 0.17X$ ($r= -0.578$, $p<0.05$, $df = 11$)

Where Y is Mg content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Mg content in inflorescences with increase in soil salinity. Magnesium content in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Zinc, Copper, Manganese and Iron Content in Tissues

Zn content in tissues

As the age of control as well as salt-stressed plants advanced, zinc content significantly increased ($p<0.01$) in leaves, stems and roots (Table 3). Moreover, increase in soil salinity significantly reduced ($p<0.01$), Zn content in leaves, stems and roots. As a result, Zn content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Zn content was maximum in leaves and minimum in roots. There was a significant negative relationship between soil salinity and Zn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 48.58 – 0.90X$ ($r = -0.816$, $p<0.01$, $df = 11$)

Stem: $Y = 45.54 – 0.78X$ ($r = -0.731$, $p<0.01$, $df = 11$)

Root: $Y = 35.93 – 0.94X$ ($r = -0.834$, $p<0.01$, $df = 11$)

Where Y is Zn content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil (dS m^{-1}).

Zinc content in inflorescences did not decrease with increase in soil salinity. Moreover, Zn content in inflorescences was almost similar at 9 and 12-week growth stages.

Cu content in tissues

As the age of control as well as salt-stressed plants advanced, Copper content significantly increased ($p<0.05$) in leaves, stems and roots (Table 3). Moreover, increase in soil salinity significantly reduced ($p<0.05$), Cu content in leaves, stems and roots. As a result, Cu content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Cu content was maximum in leaves and minimum in roots. There was a significant negative relationship between soil salinity and Cu content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 28.77 – 0.42X$ ($r = -0.686$, $p<0.01$, $df = 11$)

Stem: $Y = 24.90 – 0.59X$ ($r = -0.555$, $p<0.05$, $df = 11$)

Root: $Y = 21.15 – 0.45X$ ($r = -0.603$, $p<0.05$, $df = 11$)

Where Y is Cu content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil (dS m^{-1}).

Copper content in inflorescences did not decrease with increase in soil salinity. Moreover, Cu content in inflorescences was almost similar at 9 and 12-week growth stages.

Mn content in tissues

As the age of control and salt-stressed plants increased, Mn content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) (Table 3). Moreover, Mn content significantly increased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Manganese content was maximum in tissues of plants

grown in soil at 7.9 dS m^{-1} salinity and minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Mn content was maximum in roots and minimum in leaves. A positive relationship was found between soil salinity and Mn content in leaves at 12-week growth stage according to the following expressions:

Leaf: $Y = 47.14 + 1.46X$ ($r = 0.936$, $p<0.01$, $df = 11$)

Stem: $Y = 51.87 + 1.85X$ ($r = 0.935$, $p<0.01$, $df = 11$)

Root: $Y = 60.14 + 1.46X$ ($r = 0.905$, $p<0.01$, $df = 11$)

Where Y is Mn content (µg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Manganese content in inflorescences did not increase significantly with increase in soil salinity. Manganese content in inflorescences was almost similar at 9 and 12-week growth stages.

Fe content in tissues

As the age of control as well as salt-stressed plants advanced, Fe content significantly increased in leaves and stems ($p<0.01$) and roots ($p<0.05$) (Table 3). In addition, Fe content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. Consequently, Fe content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Fe content was maximum in roots and minimum in leaves. There was a significant negative relationship between soil salinity and Fe content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 419.42 – 9.48X$ ($r = -0.703$, $p<0.01$, $df = 11$)

Stem: $Y = 501.11 – 9.42X$ ($r = -0.680$, $p<0.01$, $df = 11$)

Root: $Y = 638.00 – 10.60X$ ($r = -0.751$, $p<0.01$, $df = 11$)

Where Y is Fe content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

Iron content in inflorescences did not decrease with increase in soil salinity. Iron content in inflorescences was almost similar at 9 and 12-week growth stages.

Table 3. Effect of soil salinity on nutrient content of tissues (leaf, stem, root and inflorescence of *Pennisetum glaucum* variety **GHB 577** at different growth stages as indicated by mean ± SEM.

	3-week growth stage											
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	31±0.8	3.5±0.3	17.5±1.3	7.5±1.2	7±0.9	3.5±0.9	2.5±0.6	41±0.9	24.8±1.2	38±2.1	356±45.0
	3.9	30±0.7	3.1±0.5	16.5±1.3	8.3±0.7	6.3±0.6	3.2±1.0	2.0±0.2	38.5±1.6	23.6±1.5	42±1.0	330±41.6
	6	28±0.2	2.7±0.4	15±1.7	9±1.0	5.5±0.9	2.8±0.7	1.8±0.4	36±1.6	22.5±2.5	46±1.2	300±19.7
	7.9	25±0.8	2.4±0.2	13.5±1.2	9.5±0.9	5±0.9	2.4±0.7	1.5±0.2	33±1.4	21.5±2.1	50±1.0	273±22.4
Stem	**0.3**	28±0.5	3±0.3	16±1.3	6±1.0	8.8±0.6	5.6±0.6	2.8±0.3	40±1.1	20.5±2.5	42±2.0	421±34.1
	3.9	26±0.4	2.7±0.2	15±1.8	6.8±0.9	8.3±0.6	5±0.7	2.4±0.6	37.5±1.3	19±1.6	47±0.6	400±38.1
	6	24.5±0.5	2.5±0.2	13±1.7	7.8±1.0	7.7±0.5	4.5±0.6	1.8±0.3	35±1.8	17.5±1.5	51±1.0	375±11.3
	7.9	22±0.8	2.2±0.5	11.5±1.0	8.8±0.6	7±0.9	4±0.7	1.3±0.2	33±1.8	16±2.2	54±0.6	354±17.7
Root	**0.3**	25±0.2	2.8±0.3	15±1.0	4.3±0.9	4.5±0.6	2.5±0.5	3.8±0.7	30±1.2	16.5±1.4	50±1.2	573±43.4
	3.9	23±0.9	2.4±0.3	13.5±1.0	5.3±0.7	3.8±0.4	2±0.9	2.7±0.6	27.5±1.3	15.5±1.8	54±1.0	546±45.5
	6	21.5±0.6	2.2±0.2	12±1.2	6.3±0.9	3.2±0.1	1.6±0.5	1.9±0.2	25.5±1.7	14.5±2.5	58±0.6	517±14.0
	7.9	20±0.5	1.9±0.3	11±1.2	7±0.8	2.6±0.5	1.2±0.4	1.6±0.4	22.5±1.3	13±1.3	61±1.5	489±29.1

Table 3. (Continued)

		6-week growth stage										
	Salinity ($dS\ m^{-1}$)	**N ($mg\ g^{-1}$)**	**P ($mg\ g^{-1}$)**	**K ($mg\ g^{-1}$)**	**Na ($mg\ g^{-1}$)**	**Ca ($mg\ g^{-1}$)**	**Mg ($mg\ g^{-1}$)**	**K/Na ratio**	**Zn ($\mu g\ g^{-1}$)**	**Cu ($\mu g\ g^{-1}$)**	**Mn ($\mu g\ g^{-1}$)**	**Fe ($\mu g\ g^{-1}$)**
Leaf	**0.3**	33±0.8	3.8±0.3	19±1.0	8.8±0.7	7.8±1.0	4±0.8	2.2±0.1	44±1.8	26.5±2.3	42±1.5	378±17.4
	3.9	31.5±0.6	3.4±0.2	17.5±1.3	9.5±1.0	7±1.3	3.7±1.1	1.9±0.1	41.5±0.8	25.5±1.2	46±0.6	350±41.6
	6	29±0.2	3±0.3	16±1.2	10.2±0.9	6.3±0.6	3.4±0.5	1.6±0.2	39.5±0.9	24.2±1.4	50±1.0	326±7.0
	7.9	26.6±0.8	2.7±0.3	14.5±1.0	10.8±0.7	5.8±0.8	2.9±0.4	1.3±0.1	37±1.0	23.3±2.3	53±0.6	300±19.7
Stem	**0.3**	30±0.6	3.3±0.5	17.5±0.9	7.3±0.7	9.5±0.9	6.2±1.0	2.3±0.2	41.5±1.9	22±1.7	46±0.6	449±15.5
	3.9	27.5±0.8	3±0.3	16.3±1.7	8±1.1	9±1.0	5.5±1.0	2.2±0.5	39±1.1	20.5±2.5	51±1.0	427±28.9
	6	26±0.9	2.8±0.4	14.5±0.8	9±1.2	8.4±1.3	5±0.5	1.7±0.2	37±1.5	19.3±1.8	55±1.2	402±37.2
	7.9	24±0.9	2.5±0.3	13±1.2	9.8±0.6	7.8±0.9	4.6±0.7	1.3±0.1	35±1.4	17.5±1.5	59±1.7	378±13.9
Root	**0.3**	27.8±0.5	3.1±0.2	16.5±1.3	5.5±0.8	5.1±0.2	3±0.8	3.0±0.4	32±1.1	18.5±1.4	54±1.0	592±25.5
	3.9	24.5±0.8	2.7±0.3	15±0.8	6.4±1.4	4.5±0.2	2.6±0.4	2.7±0.8	29.5±1.1	17.3±2.6	58±1.2	567±34.2
	6	23±0.5	2.5±0.3	13.5±0.9	7.3±1.4	4±0.4	2.2±0.6	1.9±0.2	27.5±1.7	16.3±1.4	62±1.2	542±46.7
	7.9	22±0.3	2.2±0.4	12.5±0.8	8±1.5	3.5±0.5	1.8±0.6	1.6±0.2	25±1.1	15±1.2	65±1.5	513±12.9

Table 3. (Continued)

		9-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	34±0.7	4.1±0.3	20±1.2	10±0.5	8.5±1.1	4.5±0.7	2±0.1	46±0.8	27.8±1.7	45±1.0	393±9.5
	3.9	32.5±0.7	3.7±0.2	18.5±1.8	10.8±1.2	7.7±0.9	4.1±0.6	1.7±0.1	43.5±1.1	26.7±2.1	49±2.1	370±21.3
	6	30±0.8	3.3±0.4	17±1.5	11.5±1.0	7±0.8	3.8±0.6	1.5±0.2	41.5±1.4	25.5±1.2	53±1.2	345±29.1
	7.9	27.5±0.8	3±0.3	15.5±1.0	12.2±0.9	6.3±0.9	3.4±0.9	1.3±0.1	39±1.3	24.5±2.3	56±1.5	321±3.0
Stem	**0.3**	31±0.5	3.6±0.2	18.5±1.0	8.5±0.8	10±1.3	6.5±0.9	2.0±0.1	43±1.0	23.5±1.3	50±0.6	475±28.3
	3.9	28.5±0.8	3.3±0.2	17.3±1.0	9.2±1.0	9.5±0.6	5.9±0.6	1.9±0.1	41±1.6	22±1.7	54±1.2	450±16.4
	6	27±0.9	3±0.6	15.5±1.3	10±0.6	9±0.7	5.4±0.7	1.5±0.3	39±1.3	20.5±2.5	59±0.6	428±28.0
	7.9	25.5±0.8	2.7±0.3	14±1.0	10.7±0.7	8.4±0.6	5±0.7	1.3±0.2	37±1.3	18.8±1.0	62±1.2	400±35.2
Root	**0.3**	28.5±0.7	3.3±0.2	18±1.7	6.5±0.8	5.7±0.6	3.5±0.8	2.9±0.7	33.5±1.6	19.8±2.3	58±0.6	610±12.1
	3.9	26±0.5	2.9±0.4	16.5±1.6	7.3±1.2	5.1±0.3	3±0.6	2.4±0.4	31±1.2	18.5±1.4	62±1.2	585±33.1
	6	24.5±0.3	2.7±0.2	14.5±1.3	8.1±1.5	4.6±0.5	2.7±0.6	1.9±0.3	29±1.7	17.3±2.6	65±1.5	560±39.1
	7.9	23±0.5	2.4±0.1	13.5±1.6	8.8±0.9	4.1±0.2	2.3±0.6	1.6±0.3	27±1.1	16±1.6	68±1.0	533±9.2
Inflor.	**0.3**	34.5±0.4	4.3±0.2	20.2±0.4	10.1±0.9	8.8±0.7	4.7±0.5	2.0±0.2	46.3±0.9	28±0.1	46±0.6	395±40.4
	3.9	34.2±0.4	4±0.2	19.9±0.5	10.8±0.7	8.5±1.1	4.5±0.7	1.9±0.1	46±0.9	27.7±0.3	48±1.7	384±41.1
	6	33.7±0.9	3.8±0.1	19.3±0.2	11.3±1.1	8.3±0.6	4±0.8	1.7±0.2	45.8±1.2	27.5±1.3	49±1.3	379±17.2
	7.9	33.5±0.6	3.6±0.2	19±0.1	11.5±1.1	8±0.6	3.8±0.6	1.7±0.2	45.5±1.0	27±0.9	51±1.7	370±21.3

Table 3. (Continued)

		12-week growth stage										
	Salinity	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**K/Na**	**Zn**	**Cu**	**Mn**	**Fe**
	(dS m^{-1})	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**ratio**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**
Leaf	**0.3**	34.5±0.4	4.3±0.3	21.5±0.8	11±0.8	9±0.6	4.8±1.2	2.0±0.1	48±0.9	28.5±1.3	48±0.6	413±16.5
	3.9	33±0.5	3.9±0.3	20±1.3	12±1.5	8.3±0.6	4.5±0.7	1.7±0.2	45.5±1.0	27.4±2.2	52±1.5	388±17.1
	6	30.5±0.5	3.5±0.1	18.5±1.6	12.7±0.9	7.5±0.5	4.2±0.6	1.5±0.1	43.5±1.7	26.3±2.8	56±1.2	365±16.4
	7.9	28±0.6	3.2±0.3	17±1.5	13.4±1.2	6.7±0.7	3.8±0.6	1.3±0.2	41±1.2	25.3±1.0	59±0.6	340±24.4
Stem	**0.3**	32±0.8	3.8±0.4	20±1.6	9.5±0.8	10.5±1.0	6.8±1.0	1.9±0.3	45±1.3	24.5±1.4	53±1.5	495±14.0
	3.9	29±0.7	3.5±0.5	18.5±0.8	10.3±0.9	9.8±0.9	6.3±0.8	1.8±0.1	43±1.4	23±1.1	58±0.6	470±24.2
	6	27.5±0.4	3.2±0.2	16.5±0.9	11.1±1.1	9.4±1.0	5.8±0.6	1.5±0.1	41±1.2	21.5±2.1	63±2.0	446±16.3
	7.9	26±0.7	2.9±0.4	15±1.5	11.7±1.1	8.8±0.7	5.4±0.6	1.3±0.2	39±1.8	20±2.2	67±0.6	423±23.7
Root	**0.3**	29±0.7	3.4±0.4	19.5±1.3	7.2±0.7	6.4±0.7	3.9±0.6	2.8±0.3	35.5±1.4	20.8±1.3	61±1.5	630±18.6
	3.9	26.5±0.6	3±0.3	17.5±1.0	8±1.1	5.7±0.6	3.4±0.7	2.2±0.2	32.5±1.0	19.8±2.3	65±1.5	605±7.1
	6	25.5±0.6	2.8±0.4	15.5±1.6	9±1.6	5.2±0.7	3±0.4	1.9±0.5	30.5±1.3	18.5±1.4	69±1.2	576±29.0
	7.9	24±0.7	2.5±0.3	14±1.5	9.7±0.6	4.7±0.6	2.6±0.7	1.5±0.2	28.3±1.2	17.4±2.7	72±1.0	549±9.2
Inflor.	**0.3**	35.6±0.5	4.5±0.3	20.5±0.4	10.6±0.7	9±0.7	4.9±1.0	2.0±0.2	46.8±1.0	28.4±0.5	47±1.0	410±33.3
	3.9	35.4±0.6	4.4±0.3	20.1±0.3	11.2±1.2	8.7±0.3	4.7±0.5	1.8±0.2	46.5±0.7	28.1±0.2	49±1.5	390±37.0
	6	35±0.2	4.1±0.2	19.5±0.1	11.5±1.0	8.5±1.1	4.4±0.5	1.7±0.2	46±0.8	27.8±0.3	51±1.7	385±40.4
	7.9	34.8±0.5	3.8±0.3	19.2±0.2	11.7±1.1	8.2±0.7	4±0.8	1.7±0.2	45.8±1.2	27.5±1.3	53±2.0	380±16.8

Variety GHB 734

Effect of Salinity on Sodium and Potassium Content and K/Na Ratio in Tissues.

Na content in tissues

Sodium content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 4). Moreover, Na content in tissues significantly increased ($p<0.01$) with increase of salt concentration in soil. As a result, Na content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Na content was maximum in leaves and minimum in roots. There was a positive relationship between soil salinity and Na content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 11.83 + 0.33X$ ($r = 0.578$, $p<0.05$, $df = 11$)

Stem: $Y = 10.55 + 0.35X$ ($r = 0.557$, $p<0.05$, $df = 11$)

Root: $Y = 8.55 + 0.35X$ ($r = 0.593$, $p<0.05$, $df = 11$)

Where Y is Na content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant increase in Na content in inflorescences with the increase in soil salinity. Sodium content in inflorescences was almost similar at 9 and 12-week growth stages.

K content in tissues

Potassium content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 4). Further, K content significantly decreased ($p<0.01$) in leaves, stems and roots with increase of salt concentration in soil. As a result, K content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants K content was maximum in leaves and minimum in roots. A significant negative relationship was found between soil salinity and k content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 16.86 – 0.47X$ ($r = -0.601$, $p<0.05$, $df = 11$)

Stem: $Y = 16.36 – 0.47X$ ($r = -0.565$, $p<0.05$, $df = 11$)

Root: $Y = 14.77 – 0.39X$ ($r = -0.576$, $p<0.05$, $df = 11$)

Where Y is K content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in K content in inflorescences with increase in soil salinity. Further, K content in inflorescences was almost similar at 9 and 12-week growth stages.

K/Na ratio in tissues

There was no significant change in K/Na ratio of leaves, stems and roots with increase in age of control as well as salt-stressed plants (Table 4). The K/Na ratio significantly decreased ($p<0.01$) in leaves, stems and roots of plants as the soil salinity increased. Consequently, K/Na ratio was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. A negative relationship was obtained between soil salinity and K/Na ratio in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 1.45 – 0.07X$ ($r = -0.613$, $p<0.05$, $df = 11$)

Stem: $Y = 1.56 – 0.08X$ ($r = -0.789$, $p<0.01$, $df = 11$)

Root: $Y = 1.69 – 0.08X$ ($r = -0.855$, $p<0.01$, $df = 11$)

Where Y is K/Na ratio of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant change in K/Na ratio in inflorescences with the increase in soil salinity. The K/Na ratio in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Nitrogen, Phosphorus, Calcium and Magnesium Content in Tissues

N content in tissues

Nitrogen content significantly increased ($p<0.05$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 4). Increase in soil salinity caused a significant reduction in N content of leaves and stems ($p<0.01$) and roots ($p<0.05$) of control and salt-stressed plants. Nitrogen content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants N content was maximum in leaves and minimum in roots at all the growth stages. There was a negative relationship between soil salinity and N content of tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 30.44 – 0.89X$ ($r = -0.549$, $p<0.05$, $df = 11$)

Stem: $Y = 27.94 – 1.04X$ ($r = -0.686$, $p<0.01$, $df = 11$)

Root: $Y = 24.33 – 0.87X$ ($r = -0.576$, $p<0.05$, $df = 11$)

Where Y is N content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in N content in inflorescences with the increase in soil salinity. Nitrogen content in inflorescences was almost similar at 9 and 12-week growth stages.

P content in tissues

Phosphorus content significantly increased in leaves ($p<0.01$), stems ($p<0.01$) and roots ($p<0.05$) as the age of control and salt-stressed plants increased (Table 4). In addition, P content significantly decreased in leaves ($p<0.01$), stems ($p<0.01$) and roots ($p<0.05$) with increase of salt concentration in soil. As a result, P content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants P content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was found between soil salinity and P content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 3.96 – 0.10X$ ($r = -0.576$, $p<0.05$, $df = 11$)

Stem: $Y = 3.76 – 0.11X$ ($r= -0.639$, $p<0.05$, $df = 11$)

Root: $Y = 3.06 – 0.11X$ ($r = -0.572$, $p<0.05$, $df = 11$)

Where Y is P content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in P content in inflorescences with increase in soil salinity. Further, P content in inflorescences was almost similar at 9 and 12-week growth stages.

Ca content in tissues

As the age of control as well as salt-stressed plants advanced, calcium content significantly increased ($p<0.01$) in leaves, stems and roots (Table 4). Increase in soil salinity significantly reduced Ca content in leaves and stems ($p<0.05$) and roots

($p<0.01$). Calcium content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Ca content was maximum in stems and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and Ca content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 8.24 – 0.26X$ ($r = -0.562$, $p<0.05$, $df = 11$)

Stem: $Y = 9.62 – 0.21X$ ($r = -0.597$, $p<0.05$, $df = 11$)

Root: $Y = 6.73 – 0.36X$ ($r = -0.669$, $p<0.05$, $df =11$)

Where Y is Ca content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Calcium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Ca content in inflorescences was almost similar at 9 and 12-week growth stages.

Mg content in tissues

As the age of control as well as salt-stressed plants advanced, magnesium content significantly increased ($p<0.01$) in leaves, stems and roots (Table 4). Moreover, increase in soil salinity significantly reduced ($p<0.05$) Mg content in leaves, stems and roots. As a result, Mg content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Mg content was maximum in stems and minimum in roots at all the growth stages.

There was a significant negative relationship between soil salinity and Mg content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.10 – 0.13X$ ($r = -0.553$, $p<0.05$, $df = 11$)

Stem: $Y = 5.10 – 0.13X$ ($r = -0.579$, $p<0.05$, $df = 11$)

Root: $Y = 3.47 – 0.13X$ ($r = -0.563$, $p<0.05$, $df = 11$)

Where Y is Mg content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Magnesium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Mg content in inflorescences was almost similar at 9 and 12-week growth stages.

Effect of Salinity on Zinc, Copper, Manganese and Iron Content in Tissues

Zn content in tissues

Zinc content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 4). Increase in soil salinity significantly reduced ($p<0.01$), Zn content in leaves, stems and roots. Zinc content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Zn content was maximum in leaves and minimum in roots. A significant negative relationship was obtained between soil

salinity and Zn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 43.44 – 0.71X$ ($r = -0.846$, $p<0.01$, $df = 11$)

Stem: $Y = 41.85 – 0.69X$ ($r = -0.757$, $p<0.01$, $df = 11$)

Root: $Y = 34.54 – 0.78X$ ($r = -0.769$, $p<0.01$, $df =11$)

Where Y is Zn content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

There was no significant decrease in Zn content in inflorescences with increase in soil salinity. Further, Zn content in inflorescences was almost similar at 9 and 12-week growth stages.

Cu content in tissues

Copper content significantly increased in leaves ($p<0.05$), stems and roots ($p<0.01$) as the age of control and salt-stressed plants increased (Table 4). Increase in soil salinity caused a significant reduction in Cu content of leaves ($p<0.05$), stems and roots ($p<0.01$) of control and salt-stressed plants. Copper content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 $dS\ m^{-1}$ salinity. Among the leaves, stems and roots of both control and salt-stressed plants Cu content was maximum in leaves and minimum in roots. A significant negative relationship was obtained between soil salinity and Cu content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 26.31 – 0.41X$ ($r = -0.648$, $p<0.05$, $df = 11$)

Stem: $Y = 22.24 – 0.48X$ ($r = -0.689$, $p<0.01$, $df = 11$)

Root: $Y = 19.30 – 0.55X$ ($r = -0.659$, $p<0.05$, $df =11$)

Where Y is Cu content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Cu content in inflorescences with increase in soil salinity. Further, Cu content in inflorescences was almost similar at 9 and 12-week growth stages.

Mn content in tissues

Manganese content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 4). Further, Mn content in tissues significantly increased ($p<0.01$) with increase of salt concentration in soil. Consequently, Mn content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Mn content was maximum in roots and minimum in leaves. There was a positive relationship between soil salinity and Mn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 54.72 + 1.71X$ ($r = 0.891$, $p<0.01$, $df = 11$)

Stem: $Y = 58.91 + 1.57X$ ($r = 0.863$, $p<0.01$, $df = 11$)

Root: $Y = 61.06 + 1.69X$ ($r = 0.905$, $p<0.01$, $df = 11$)

Where Y is Mn content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant increase in Mn content in inflorescences with the increase in soil salinity. Manganese content in inflorescences was almost similar at 9 and 12-week growth stages.

Fe content in tissues

Iron content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 4). Moreover, increase in soil salinity significantly decreased ($p<0.01$), Fe content in leaves, stems and roots. Iron content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Fe content was maximum in roots and minimum in leaves. A significant negative relationship was obtained between soil salinity and Fe content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 516.22 – 10.21X$ ($r = -0.552$, $p<0.05$, $df = 11$)

Stem: $Y = 563.10 – 10.35X$ ($r = -0.694$, $p<0.01$, $df = 11$)

Root: $Y = 630.00 – 11.77X$ ($r = -0.697$, $p<0.01$, $df = 11$)

Where Y is Fe content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Fe content in inflorescences with increase in soil salinity. Further, Fe content in inflorescences was almost similar at 9 and 12-week growth stages.

Table 4. Effect of soil salinity on nutrient content of tissues (leaf, stem, root and inflorescence of *Pennisetum glaucum* variety **GHB 734** at different growth stages as indicated by mean ± SEM.

		3-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	25±2.3	3.1±0.2	13.5±1.3	9±1.0	6±0.5	2.7±0.8	1.6±0.3	38±1.7	22.5±1.5	43±1.0	440±18.0
	3.9	23±1.2	2.8±0.4	12.5±1.3	9.8±0.8	5.3±0.6	2.3±1.0	1.3±0.4	36±1.0	21±1.7	47±1.5	413±32.4
	6	21.5±0.3	2.6±0.2	11±1.0	10.6±0.8	4.7±1.0	2±0.7	1.1±0.2	34±0.8	20±1.2	51±2.3	380±16.8
	7.9	19.5±0.3	2.3±0.2	10±1.5	11.5±0.9	4±0.9	1.7±0.6	0.9±0.1	32±1.0	19±1.0	55±1.5	350±25.5
Stem	**0.3**	22±1.2	2.8±0.4	12.5±0.9	7.8±0.4	7.5±0.9	3.8±0.2	1.6±0.2	35±1.0	19±0.7	46±1.2	473±39.9
	3.9	19.5±3.8	2.5±0.2	11.5±0.8	8.7±0.9	6.8±0.4	3.3±0.7	1.4±0.2	33±1.2	17.3±0.9	50±1.5	447±41.6
	6	18±2.0	2.2±0.2	10±0.3	9.7±0.6	6.1±0.9	2.8±0.2	1.0±0.4	31±1.4	16±1.1	54±1.0	423±14.4
	7.9	17±0.6	2±0.1	9±1.0	10.5±0.9	5.7±1.1	2.5±0.5	0.9±0.2	29±1.8	15±0.7	58±2.1	397±16.3
Root	**0.3**	19.5±1.5	2.1±0.2	11±1.7	6±0.8	3.8±0.7	2±0.5	1.9±0.4	28±1.6	16±1.1	50±1.5	560±42.5
	3.9	17±0.9	1.8±0.2	10±1.2	7±0.9	3.2±0.9	1.7±0.5	1.4±0.1	25.5±1.6	14.5±1.0	54±2.1	520±22.9
	6	15.9±1.2	1.5±0.3	9±0.6	8.2±0.7	2.5±0.5	1.4±0.4	1.1±0.2	23.5±1.1	13.3±1.3	59±0.6	490±21.4
	7.9	14.5±0.3	1.3±0.4	8±1.2	9.2±0.6	2±0.6	1±0.4	0.9±0.2	22±1.1	12±0.8	63±1.5	460±18.2

Table 4. (Continued)

		6-week growth stage										
	Salinity	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**K/Na**	**Zn**	**Cu**	**Mn**	**Fe**
	(dS m^{-1})	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**ratio**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**
Leaf	**0.3**	28±1.2	3.4±0.2	14.5±0.5	10±0.3	6.8±0.8	3.2±0.6	1.5±0.1	40±1.8	23.8±1.8	48±1.2	468±45.1
	3.9	25±1.7	3.1±0.2	13.5±1.8	10.7±0.7	6.3±0.7	2.8±0.8	1.3±0.2	38±0.8	22.5±1.5	52±2.1	436±15.6
	6	23.5±2.1	2.9±0.3	12±1.3	11.5±1.0	5.5±0.6	2.5±1.1	1.0±0.1	36.5±1.3	21.5±1.3	56±1.5	413±32.4
	7.9	21±1.7	2.6±0.3	11±1.2	12.5±0.8	4.9±0.8	2.2±0.7	0.9±0.1	34.5±1.4	20.5±2.5	60±1.0	382±15.6
Stem	**0.3**	24.5±2.0	3.1±0.1	13.5±0.8	8.8±1.0	8.5±0.9	4.3±0.5	1.6±0.2	37.5±1.2	20±1.0	51±2.5	503±20.6
	3.9	21.5±4.3	2.8±0.2	12.5±1.6	9.6±0.8	8±1.0	3.9±0.4	1.3±0.2	36±1.0	18.5±0.8	55±1.0	473±39.9
	6	19.6±0.8	2.5±0.2	11.5±0.9	10.6±0.8	7.3±0.9	3.5±0.1	1.1±0.1	34.5±1.1	17.2±0.8	59±1.5	446±40.7
	7.9	18.5±1.4	2.3±0.1	10.5±1.3	11.5±1.0	6.6±1.0	3.2±0.6	0.9±0.2	32.5±1.4	16±1.1	63±2.9	426±11.8
Root	**0.3**	22±2.3	2.4±0.6	12.5±1.5	7±0.9	4.5±0.7	2.6±0.3	1.9±0.5	30±1.3	17.3±1.0	54±2.1	580±4.9
	3.9	18.5±2.0	2.1±0.6	11.5±0.9	8±0.8	3.8±0.8	2.2±0.5	1.4±0.1	27.5±0.8	15.6±1.3	58±1.5	545±23.2
	6	17.5±2.0	1.8±0.2	10.5±1.0	9±0.8	3.1±0.9	1.9±0.6	1.2±0.1	25.5±1.3	14.6±1.0	63±1.5	520±22.9
	7.9	16±2.8	1.6±0.1	9.5±1.0	10±0.8	2.5±0.8	1.5±0.4	0.9±0.1	24±0.8	13.5±1.1	67±1.0	490±21.4

Table 4. (Continued)

		9-week growth stage										
	Salinity	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**K/Na**	**Zn**	**Cu**	**Mn**	**Fe**
	(dS m^{-1})	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**ratio**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**
Leaf	**0.3**	29.5±0.9	3.7±0.1	15.5±1.4	11±1.2	7.5±0.8	3.6±0.9	1.5±0.3	41.5±1.4	25±1.1	52±2.1	489±35.7
	3.9	26±2.8	3.4±0.2	14.5±1.3	11.8±0.9	6.9±1.0	3.3±0.9	1.2±0.2	39.5±0.9	24±1.3	56±1.5	460±39.1
	6	24.5±2.0	3.2±0.2	13±1.1	12.6±0.7	6.1±0.7	3±0.9	1.0±0.1	38±1.1	23±3.6	60±1.0	438±14.5
	7.9	22.5±2.6	2.9±0.4	12±0.6	13.4±0.6	5.4±0.6	2.6±0.6	0.9±0.1	36±1.2	21.8±1.3	64±2.0	410±32.3
Stem	**0.3**	27±1.2	3.4±0.2	15±1.0	10±1.0	8.9±0.8	4.7±0.7	1.5±0.1	40±1.1	21±1.3	56±1.2	531±10.8
	3.9	23.5±0.3	3.1±0.2	13.8±1.6	10.7±1.1	8.5±0.8	4.3±0.6	1.4±0.3	38±0.9	19.5±1.0	60±1.2	500±18.4
	6	20.7±3.1	2.8±0.2	12.5±0.8	11.7±0.9	8±0.5	3.9±0.4	1.1±0.1	36.3±1.3	18.3±0.9	64±2.1	473±39.9
	7.9	19.5±1.5	2.6±0.1	11.5±0.8	12.6±1.2	7.5±0.7	3.6±0.6	0.9±0.1	34.5±1.3	17±0.6	68±2.1	450±40.4
Root	**0.3**	24±3.5	2.7±0.4	13.5±1.4	8±0.9	5.5±0.9	3±0.3	1.7±0.2	32±0.9	18.2±0.6	58±1.5	600±19.1
	3.9	19.5±4.3	2.4±0.5	12.5±0.8	8.9±1.0	4.5±0.9	2.6±0.5	1.4±0.2	30±0.8	16.7±1.0	63±1.5	570±36.5
	6	18.5±2.0	2.1±0.6	11.5±1.8	9.8±1.0	3.8±0.4	2.3±0.5	1.2±0.1	28±1.3	15.7±0.9	67±1.0	540±24.7
	7.9	17.5±5.0	1.9±0.4	10.5±0.9	10.7±0.7	3.1±0.7	2±0.1	1.0±0.1	26±1.4	14.5±1.0	71±1.0	510±17.2
Inflor.	**0.3**	29.7±0.7	3.8±0.2	15.7±0.4	11.3±0.9	7.8±0.6	3.7±0.9	1.4±0.1	41.8±1.1	25.3±0.7	53±1.8	493±20.7
	3.9	29.3±0.5	3.5±0.3	15.3±0.6	11.7±0.9	7.5±0.9	3.5±0.6	1.3±0.4	41.5±1.4	25±1.3	54±2.0	487±38.7
	6	28.5±0.9	3±0.1	15±0.1	12.3±1.2	7.1±0.6	3±0.8	1.2±0.1	41.1±0.8	24.7±0.7	55±1.3	480±25.4
	7.9	28.3±1.1	2.9±0.1	14.8±0.1	12.7±1.2	6.8±0.4	2.8±0.8	1.2±0.1	40.8±1.0	24.5±0.7	57±1.5	478±20.8

Table 4. (Continued)

		12-week growth stage										
	Salinity (dS m-1)	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	30.2±0.2	3.9±0.4	16.5±1.6	12±1.3	8±0.9	4±0.6	1.4±0.2	43±0.8	26±1.4	56±1.5	510±24.8
	3.9	27±3.5	3.6±0.3	15.5±0.3	13±1.0	7.5±0.8	3.7±0.9	1.2±0.1	41±0.9	25±1.1	60±1.0	480±35.0
	6	25±1.7	3.4±0.2	14±0.6	13.8±1.5	6.8±0.9	3.4±0.5	1.0±0.2	39.5±1.0	24±1.3	65±2.1	460±39.1
	7.9	23.5±3.8	3.1±0.5	13±1.7	14.5±1.0	6±0.8	3±0.7	0.9±0.2	37.5±0.8	22.8±2.4	69±1.7	430±19.7
Stem	**0.3**	27.5±0.3	3.6±0.4	16±1.2	10.8±1.1	9.5±0.8	5±0.5	1.5±0.2	41.5±0.9	22±0.7	60±1.2	558±30.4
	3.9	24.5±1.5	3.3±0.2	15±1.2	11.7±1.0	8.9±0.6	4.7±0.8	1.3±0.2	39.5±1.5	20.5±0.9	64±2.1	527±9.9
	6	21±0.6	3±0.2	13.5±1.8	12.6±1.1	8.4±0.8	4.4±0.4	1.1±0.1	37.5±1.0	19.5±1.5	68±2.2	500±18.4
	7.9	20±4.0	2.8±0.1	12.5±1.3	13.5±1.3	7.9±0.7	4±0.3	0.9±0.1	36.3±1.4	18.3±0.7	72±1.5	480±21.5
Root	**0.3**	24.6±0.2	2.9±0.1	14.5±1.6	8.8±1.0	6.5±1.0	3.4±0.5	1.7±0.1	34±1.3	19±1.3	62±1.5	622±12.0
	3.9	20±3.5	2.6±0.4	13.5±1.3	9.7±0.9	5.5±0.5	3±0.5	1.4±0.4	32±1.3	17.8±1.0	67±1.0	590±11.1
	6	19±1.2	2.3±0.4	12.5±1.3	10.5±0.9	4.7±0.7	2.7±0.3	1.2±0.1	30±1.1	16.7±1.0	71±1.1	565±31.5
	7.9	18±5.2	2.1±0.2	11.5±0.8	11.5±1.0	3.7±0.9	2.4±0.4	1.0±0.1	28±1.4	15.5±0.8	75±2.3	530±31.8
Inflor.	**0.3**	30±0.7	3.9±0.2	15.9±0.2	11.5±0.8	8±0.9	3.9±0.8	1.4±0.1	42±0.9	25.7±0.9	55±2.1	497±18.5
	3.9	29.6±0.6	3.7±0.2	15.5±0.3	12.2±1.1	7.7±0.5	3.7±0.9	1.3±0.2	41.7±1.0	25.5±0.8	56±1.8	490±36.1
	6	28.7±0.7	3.5±0.1	15.3±0.6	12.5±1.2	7.5±0.9	3.4±0.5	1.2±0.2	41.4±0.5	25±1.3	57±1.5	486±20.6
	7.9	28.5±0.9	3.1±0.1	15±0.1	12.9±1.1	7±0.5	3±0.9	1.2±0.3	41.2±0.7	24.8±0.6	58±1.2	480±25.4

Variety GHB 743

Effect of Salinity on Sodium and Potassium Content and K/Na Ratio in Tissues.

Na content in tissues

Sodium content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 5). Further, Na content in tissues significantly increased ($p<0.01$) with increase of salt concentration in soil. As a result, Na content was maximum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity, whereas it was minimum in tissues of control plants. Among the leaves, stems and roots of both control and salt-stressed plants Na content was maximum in leaves and minimum in roots at all the growth stages. There was a positive relationship between soil salinity and Na content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 11.08 + 0.28X$ ($r = 0.554$, $p<0.05$, $df = 11$)

Stem: $Y = 9.675 + 0.34X$ ($r = 0.592$, $p<0.05$, $df = 11$)

Root: $Y = 9.33 + 0.26X$ ($r = 0.562$, $p<0.05$, $df = 11$)

Where Y is Na content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant increase in Na content in inflorescences with the increase in soil salinity. Sodium content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference among varieties for Na content in leaves ($p<0.05$), stems ($p<0.01$) and roots ($p<0.01$) in response to soil salinity. In general, Na content in tissues was greater in varieties GHB 734 and GHB 743 than that in tissues of varieties GHB 538, GHB 558 and GHB 577.

K content in tissues

Potassium content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 5). Increase in soil salinity significantly reduced K content in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$). As a result, K content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants K content was maximum in leaves and minimum in roots. A significant negative relationship was found between soil salinity and K content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 20.94 – 0.71X$ ($r = -0.945$, $p<0.01$, $df = 11$)

Stem: $Y = 18.90 – 0.59X$ ($r = -0.713$, $p<0.01$, $df = 11$)

Root: $Y = 17.48 – 0.52X$ ($r = -0.726$, $p<0.01$, $df = 11$)

Where Y is K content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in K content in inflorescences with increase in soil salinity. Further, K content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for K content in leaves, stems and roots in response to soil salinity. In general, K content in tissues was greater in varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

K/Na ratio in tissues

The K/Na ratio significantly increased in leaves ($p<0.05$), whereas it did not change significantly in stems and roots with the increase of age for control as well as salt-stressed plants (Table 5). Moreover, increase in soil salinity significantly reduced ($p<0.01$) the K/Na ratio in leaves, stems and roots. As a result, the K/Na ratio was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. There was a significant negative relationship between soil salinity and K/Na ratio in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 1.87 – 0.09X$ ($r = -0.879$, $p<0.01$, $df = 11$)

Stem: $Y = 1.95 – 0.09X$ ($r = -0.722$, $p<0.01$, $df = 11$)

Root: $Y = 1.87 – 0.09X$ ($r = -0.767$, $p<0.01$, $df = 11$)

Where Y is K/Na ratio of tissues and X is salt concentration in soil (dS m^{-1}).

The K/Na ratio in inflorescences did not change significantly in respect to increase in age and increase in soil salinity.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for K/Na ratio in leaves, stems and roots in response to soil salinity. In general, K/Na ratio in tissues was greater in varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

Effect of Salinity on Nitrogen, Phosphorus, Calcium and Magnesium Content in Tissues

N content in tissues

Nitrogen content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 5). Further, N content in tissues significantly decreased ($p<0.01$) with increase of salt concentration in soil. As a result, N content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants N content was maximum in leaves and minimum in roots at all the growth stages.

There was a negative relationship between soil salinity and N content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 30.49 – 0.79X$ ($r = -0.958$, $p<0.01$, $df = 11$)

Stem: $Y = 26.64 – 0.67X$ ($r = -0.935$, $p<0.01$, $df = 11$)

Root: $Y = 23.95 – 0.64X$ ($r = -0.910$, $p<0.01$, $df = 11$)

Where Y is N content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in N content in inflorescences with the increase in soil salinity. Nitrogen content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among verities

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for N content in leaves, stems and roots in response to soil salinity. In general, N content in tissues was greater in varieties GHB 538, GHB 558 and GHB 577 than that in tissues of verities GHB 734 and GHB 743.

P content in tissues

Phosphorus content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) as the age of control and salt-stressed plants increased (Table 5). Increase in soil salinity significantly reduced P content in leaves ($p<0.01$), stems and roots ($p<0.05$). As a result, P content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves,

stems and roots of both control and salt-stressed plants P content was maximum in leaves and minimum in roots at all the growth stages. A significant negative relationship was found between soil salinity and P content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 3.06 – 0.11X$ ($r = -0.557$, $p<0.05$, $df = 11$)

Stem: $Y = 2.84 – 0.09X$ ($r= -0.572$, $p<0.05$, $df = 11$)

Root: $Y = 3.29 – 0.03$ ($r = -0.563$, $p<0.05$, $df = 11$)

Where Y is P content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in P content in inflorescences with increase in soil salinity. Further, P content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for P content in leaves, stems and roots in response to soil salinity. In general, P content in tissues was greater in varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

Ca content in tissues

As the age of control as well as salt-stressed plants advanced, calcium content significantly increased ($p<0.05$) in leaves, stems and roots (Table 5). Moreover, increase in soil salinity significantly reduced Ca content in leaves and stems

($p<0.05$) and roots ($p<0.01$). As a result, Ca content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Ca content was maximum in stems and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and Ca content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 8.14 – 0.32X$ ($r = -0.559$, $p<0.05$, $df = 11$)

Stem: $Y = 8.72 – 0.28X$ ($r = -0.554$, $p<0.05$, $df = 11$)

Root: $Y = 3.64 – 0.19X$ ($r = -0.701$, $p<0.01$, $df = 11$)

Where Y is Ca content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Calcium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Ca content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for Ca content in leaves, stems and roots in response to soil salinity. In general, Ca content in tissues of varieties GHB 538, GHB 558 and GHB 577 was greater than that in tissues of varieties GHB 734 and GHB 743.

Mg content in tissues

As the age of control as well as salt-stressed plants advanced, magnesium content significantly increased ($p<0.01$) in leaves, stems and roots (Table 5). Increase in soil salinity significantly reduced Mg content in leaves and stems ($p<0.05$) and roots ($p<0.01$). Magnesium content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plant Mg content was maximum in stems and minimum in roots at all the growth stages. There was a significant negative relationship between soil salinity and Mg content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 4.43 – 0.17X$ ($r = -0.576$, $p<0.05$, $df = 11$)

Stem: $Y = 5.40 – 0.19X$ ($r = -0.555$, $p<0.05$, $df = 11$)

Root: $Y = 2.89 – 0.14X$ ($r = -0.656$, $p<0.05$, $df = 11$)

Where Y is Mg content (mg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

Magnesium content in inflorescences did not decrease significantly with increase in soil salinity. Moreover, Mg content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.05$) among varieties for Mg content in leaves, stems and roots in response to soil

salinity. In general, Mg content in tissues was greater in varieties GHB 538, GHB 558 and GHB 577 than that in tissues of varieties GHB 734 and GHB 743.

Effect of Salinity on Zinc, Copper, Manganese and Iron Content in Tissues

Zn content in tissues

Zinc content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 5). Increase in soil salinity caused a significant reduction ($p<0.01$) in Zn content of leaves, stems and roots of control and salt-stressed plants. As a result, Zn content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Zn content was maximum in leaves and minimum in roots. A significant negative relationship was obtained between soil salinity and Zn content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 39.04 – 0.78X$ ($r = -0.849$, $p<0.01$, $df = 11$)

Stem: $Y = 36.97 – 0.78X$ ($r = -0.814$, $p<0.01$, $df = 11$)

Root: $Y = 31.42 – 0.61X$ ($r = -0.801$, $p<0.01$, $df = 11$)

Where Y is Zn content (μg g^{-1}) of tissues and X is salt concentration in soil (dS m^{-1}).

There was no significant decrease in Zn content in inflorescences with increase in soil salinity. Further, Zn content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for Zn content in leaves, stems and roots in response to soil salinity. In general, Zn content in tissues of varieties GHB 538, GHB 558 and GHB 577 was greater than that in tissues of varieties GHB 734 and GHB 743.

Cu content in tissues

Copper content significantly increased in leaves ($p<0.01$), stems ($p<0.05$) and roots ($p<0.01$) as the age of control as well as salt-stressed plants increased (Table 5). Further, Cu content in tissues significantly decreased ($p<0.01$) with increase of salt concentration in soil. As a result, Cu content was maximum in tissues of control plants, whereas it was minimum in tissues of plants grown in soil at 7.9 dS m^{-1} salinity. Among the leaves, stems and roots of both control and salt-stressed plants Cu content was maximum in leaves and minimum in roots. There was a negative relationship between Cu content in tissues at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 21.53 – 0.43X$ ($r = -0.613$, $p<0.05$, $df = 11$)

Stem: $Y = 19.00 – 0.46X$ ($r = -0.591$, $p<0.05$, $df = 11$)

Root: $Y = 14.25 – 0.49X$ ($r = -0.669$, $p<0.05$, $df = 11$)

Where Y is Cu content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

There was no significant decrease in Cu content in inflorescences with the increase in soil salinity. Copper content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for Cu content in leaves, stems and roots in response to soil salinity. Unlike the concentration of major nutrients, Cu content in tissues of varieties GHB 538, GHB 558 and GHB 577 was not greater than that in tissues of varieties GHB 734 and GHB 743.

Mn content in tissues

Manganese content significantly increased ($p<0.01$) in tissues (leaves, stems and roots) as the age of control as well as salt-stressed plants increased (Table 5). Moreover, Mn content in tissues significantly increased ($p<0.01$) with increase of salt concentration in soil. As a result, Mn content was maximum in tissues of plants grown in soil at 7.9 $dS\ m^{-1}$ salinity, whereas it was minimum in tissues of control plants among the leaves, stems and roots of both control and salt-stressed plants Mn content was maximum in roots and minimum in leaves. There was a positive relationship between Mn content in tissues at 12-week growth period and soil salinity according to the following expressions:

Leaf: $Y = 43.18 + 1.18X$ ($r = 0.893$, $p<0.01$, $df = 11$)

Stem: $Y = 49.41 + 1.07X$ ($r = 0.936$, $p<0.01$, $df = 11$)

Root: $Y = 52.18 + 1.17X$ ($r = 0.888$, $p<0.01$, $df = 11$)

Where Y is Mn content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

There was no significant increase in Mn content in inflorescences with the increase in soil salinity. Further, Mn content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for Mn content in leaves, stems and roots in response to soil salinity. Unlike the concentration of major nutrients, Mn content in tissues of varieties GHB 538, GHB 558 and GHB 577 was not greater than that in tissues of varieties GHB 734 and GHB 743.

Fe content in tissues

Iron content significantly increased ($p<0.01$) in leaves, stems and roots as the age of control and salt-stressed plants increased (Table 5). Increase in soil salinity caused a significant reduction ($p<0.01$) in Fe content of leaves, stems and roots of control and salt-stressed plants. As a result, Fe content was maximum in tissues of control plants and minimum in tissues of plants grown in soil at 7.9 $dS\ m^{-1}$ salinity. Among the leaves, stems and roots of both control and salt-stressed plants Fe content was maximum in roots and minimum in leaves. A significant negative relationship was

obtained between soil salinity and Fe content in tissues at 12-week growth stage according to the following expressions:

Leaf: $Y = 575.62 – 11.35X$ ($r = -0.703$, $p<0.01$, $df = 11$)

Stem: $Y = 653.00 – 12.04X$ ($r = -0.841$, $p<0.01$, $df = 11$)

Root: $Y = 705.61 – 11.88X$ ($r = -0.682$, $p<0.01$, $df = 11$)

Where Y is Fe content ($\mu g\ g^{-1}$) of tissues and X is salt concentration in soil ($dS\ m^{-1}$).

There was no significant decrease in Fe content in inflorescences with increase in soil salinity. Further, Fe content in inflorescences was almost similar at 9 and 12-week growth stages.

Variation among varieties

A two way ANOVA suggested that there was a significant difference ($p<0.01$) among varieties for Fe content in leaves, stems and roots in response to soil salinity. Unlike the concentration of major nutrients, Fe content in tissues of varieties GHB 538, GHB 558 and GHB 577 was not greater than that in tissues of varieties of GHB 734 and GHB 743.

Table 5. Effect of soil salinity on nutrient content of tissues (leaf, stem, root and inflorescence of *Pennisetum glaucum* variety **GHB 743** at different growth stages as indicated by mean ± SEM.

		3-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	25.8±0.7	2.2±0.6	13±0.1	8.2±0.7	5.8±0.9	2.5±0.6	1.6±0.1	34.5±1.2	18.3±0.9	37±0.6	498±33.3
	3.9	23.5±0.3	1.9±0.1	12±0.6	9±0.8	5±0.8	2±0.6	1.4±0.1	31.5±0.9	17±1.3	40±1.5	463±45.7
	6	21.5±0.3	1.6±0.3	10.5±0.5	9.7±0.9	4.5±1.0	1.6±0.5	1.1±0.1	29.5±0.9	16±1.3	43±1.0	432±24.1
	7.9	20.5±0.9	1.4±0.2	9±0.3	10.5±0.8	4±0.8	1.2±0.4	0.9±0.2	27±1.2	15±0.9	46±0.6	407±56.1
Stem	**0.3**	22.5±0.3	1.9±0.1	12±1.5	7±0.8	6.8±0.7	3.7±0.9	1.8±0.3	33±0.9	16±1.4	43±1.0	570±29.7
	3.9	20.5±0.4	1.6±0.3	10.5±1.0	7.7±0.9	6.2±1.1	3±1.3	1.4±0.3	30.5±1.0	14.8±1.4	46±0.6	535±27.2
	6	19±0.6	1.4±0.3	9.5±1.3	8.4±0.7	5.5±0.5	2.5±0.6	1.2±0.2	28.5±0.8	13.8±1.0	48±0.6	500±4.3
	7.9	17.5±0.2	1.2±0.2	8.5±1.0	9±0.8	4.8±0.7	2.3±0.9	0.9±0.1	26.3±1.0	12.5±0.9	50±1.0	465±11.9
Root	**0.3**	19±0.2	1.7±0.2	11.5±1.3	5.5±0.8	2.5±0.6	1.8±0.3	2.2±0.5	28±1.1	11±1.3	45±1.0	621±18.9
	3.9	18±0.6	1.5±0.3	10±1.0	6.4±1.0	1.9±0.2	1.5±0.3	1.6±0.1	26±1.3	9.5±0.9	48±1.2	590±36.8
	6	16.5±0.8	1.3±0.2	8.5±1.3	7.3±1.2	1.6±0.2	1.2±0.4	1.2±0.2	24.3±0.9	8.3±0.8	51±1.0	563±31.7
	7.9	15±0.2	1.1±0.6	7±1.2	8±0.9	1.2±0.4	1±0.3	0.9±0.2	22.5±1.3	7±0.9	54±1.0	534±33.1

Table 5. (Continued)

		6-week growth stage										
	Salinity	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**K/Na**	**Zn**	**Cu**	**Mn**	**Fe**
	(dS m^{-1})	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**ratio**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**
Leaf	**0.3**	28±0.6	2.5±0.2	15.5±0.5	9.3±0.6	6.5±0.9	3.5±0.7	1.7±0.2	36.5±1.2	19.5±1.1	40±1.5	525±19.2
	3.9	25±0.3	2.2±0.3	14.5±0.4	10±1.0	5.8±0.9	3±1.0	1.5±0.2	34±1.3	18.3±1.4	43±1.0	495±19.1
	6	23.5±0.3	1.9±0.1	13.5±0.3	10.8±0.7	5.3±0.8	2.5±1.0	1.3±0.1	32±1.1	17.3±1.4	46±0.6	465±36.9
	7.9	22±1.2	1.7±0.2	12±0.6	11.5±0.9	4.8±0.7	2±0.9	1.0±0.1	30±0.6	16.3±1.1	49±1.5	440±37.9
Stem	**0.3**	24.8±0.1	2.2±0.2	14.5±1.9	8±0.9	7.3±1.0	4.2±0.6	1.9±0.4	34.5±1.2	17±1.2	46±0.6	600±39.3
	3.9	22±0.8	1.9±0.4	13.5±1.3	8.7±0.7	6.7±0.9	3.7±0.7	1.5±0.1	32±0.8	15.8±1.2	49±1.2	565±16.0
	6	20.5±0.7	1.7±0.2	12±1.5	9.5±0.9	6.2±0.7	3.2±0.7	1.3±0.2	30±0.5	14.7±1.1	52±0.6	530±26.4
	7.9	19.5±0.3	1.5±0.1	11±1.0	10.2±0.6	5.5±1.3	2.8±0.9	1.1±0.1	28±1.1	13.5±1.1	54±1.2	500±24.2
Root	**0.3**	21.5±0.6	1.9±0.1	13.5±1.8	7±0.7	2.8±0.6	2.2±0.2	1.9±0.1	29±1.4	12±1.2	48±1.5	645±10.1
	3.9	20±0.8	1.7±0.2	12.5±1.8	7.8±0.4	2.3±0.5	1.9±0.5	1.6±0.2	27±1.9	10.5±0.9	51±1.0	616±21.7
	6	18±0.5	1.5±0.3	11±1.5	8.6±1.3	1.9±0.6	1.6±0.6	1.3±0.1	26±1.0	9.5±1.0	54±1.0	585±47.5
	7.9	16.5±0.7	1.3±0.4	9.5±1.3	9.2±0.6	1.7±0.7	1.3±0.3	1.0±0.2	24.5±1.5	8.5±0.9	57±1.2	560±45.6

Table 5. (Continued)

		9-week growth stage										
	Salinity (dS m^{-1})	**N (mg g^{-1})**	**P (mg g^{-1})**	**K (mg g^{-1})**	**Na (mg g^{-1})**	**Ca (mg g^{-1})**	**Mg (mg g^{-1})**	**K/Na ratio**	**Zn (µg g^{-1})**	**Cu (µg g^{-1})**	**Mn (µg g^{-1})**	**Fe (µg g^{-1})**
Leaf	**0.3**	30.2±0.5	2.8±0.4	18±0.7	10.3±0.9	7.3±0.6	4±0.5	1.8±0.2	37.5±0.9	20.5±1.2	42±0.6	548±17.6
	3.9	26.5±0.6	2.5±0.3	17±0.2	11±1.2	6.5±1.3	3.5±0.6	1.6±0.2	35±1.2	19.3±1.2	45±1.0	520±8.1
	6	24.5±0.3	2.2±0.1	15.5±0.5	11.8±0.6	5.9±0.7	3±0.8	1.3±0.1	33.2±0.8	18.3±1.3	48±1.2	490±15.9
	7.9	23.5±0.6	2±0.2	14±0.2	12.5±1.0	5.3±0.7	2.5±1.2	1.1±0.1	31±1.2	17.5±1.1	51±0.6	459±27.7
Stem	**0.3**	26±0.4	2.5±0.3	17.5±1.3	8.9±1.1	7.8±0.8	4.8±0.7	2.0±2.0	35.5±0.8	18±1.3	48±0.6	621±18.9
	3.9	23.5±0.3	2.2±0.2	16±1.2	9.8±0.7	7.2±0.7	4.3±0.7	1.7±1.7	33.3±1.2	16.8±1.5	51±1.2	590±36.8
	6	22±0.6	2±0.5	14.5±1.6	10.6±0.6	6.6±0.7	3.8±0.8	1.4±1.4	31.5±0.8	15.5±1.2	54±0.6	558±29.3
	7.9	21±0.2	1.8±0.4	13±1.2	11.5±1.0	6±0.8	3.3±1.1	1.2±1.2	29.5±1.2	14.3±1.1	56±1.0	531±32.3
Root	**0.3**	23.5±0.8	2.1±0.2	15.5±1.0	8.3±0.6	3.2±0.5	2.5±0.5	1.9±0.2	30.1±1.3	13±1.4	51±0.6	673±18.4
	3.9	21.5±0.3	1.9±0.1	14.5±1.4	9±1.0	2.6±0.2	2.2±0.1	1.7±0.4	28.3±0.9	11.4±1.2	53.5±0.8	640±25.4
	6	19±0.6	1.7±0.4	13±1.0	9.7±0.7	2.2±0.6	1.9±0.2	1.4±0.1	27.2±1.1	10.5±1.1	57±1.0	615±24.5
	7.9	18.7±0.7	1.5±0.3	11.5±1.6	10.3±0.4	1.8±0.4	1.5±0.3	1.1±0.2	25.5±0.6	9.5±0.9	60±1.2	585±20.4
Inflor.	**0.3**	30.5±0.8	3±0.2	18.3±0.2	10±0.4	7±0.3	4.3±0.6	1.8±0.1	37.8±0.6	20.7±0.9	43±2.3	550±15.7
	3.9	26.8±0.7	2.7±0.2	18±0.1	10.7±0.7	6.3±0.2	3.7±0.4	1.7±0.1	35.5±0.9	19.5±1.2	46±1.5	535±60.3
	6	24.7±0.2	2.5±0.2	17.9±0.2	11.5±1.2	5.5±0.5	3.5±0.3	1.7±0.2	33.5±0.5	18.6±1.3	49±4.2	495±19.6
	7.9	23.2±0.5	2.3±0.1	17.5±0.3	12.1±0.4	5±0.1	2.8±0.8	1.4±0.1	32±0.9	17.7±1.1	52±0.6	465±29.7

Table 5. (Continued)

		12-week growth stage										
	Salinity	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**K/Na**	**Zn**	**Cu**	**Mn**	**Fe**
	(dS m^{-1})	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**(mg g^{-1})**	**ratio**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**	**(µg g^{-1})**
Leaf	**0.3**	30.5±0.3	3±0.3	20.5±0.5	11.3±0.4	8±0.8	4.3±0.8	1.8±0.1	38.5±1.0	21.3±1.1	44±1.0	567±32.4
	3.9	27±0.6	2.7±0.2	18.5±0.3	12±0.8	7±0.8	3.9±1.0	1.6±0.1	36.5±1.3	20.1±1.2	47±1.5	540±22.8
	6	25.5±0.4	2.4±0.3	17±0.6	12.7±0.9	6.2±1.1	3.5±0.8	1.4±0.2	34.5±0.8	18.9±1.2	50±1.2	510±6.4
	7.9	24.5±0.5	2.2±0.5	15±0.3	13.5±1.3	5.6±1.1	3±0.8	1.1±0.1	32.5±0.5	18.1±0.9	53±0.6	480±20.3
Stem	**0.3**	26.5±0.2	2.7±0.5	18.5±0.9	9.9±0.9	8.5±0.9	5.3±0.7	1.9±0.1	36.5±1.4	18.7±1.4	50±0.6	645±10.2
	3.9	24±0.3	2.4±0.5	17±1.5	10.8±1.1	7.8±0.7	4.7±0.6	1.6±0.3	34.3±0.8	17.5±1.3	53±1.2	615±24.3
	6	22.5±0.4	2.2±0.2	15.5±1.3	11.6±0.8	7.2±0.9	4.3±0.8	1.4±0.2	32.5±1.4	16.3±1.2	56±0.6	580±7.9
	7.9	21.5±0.8	2±0.3	14±0.6	12.5±0.8	6.3±0.8	3.8±1.0	1.1±0.1	30.5±0.6	15.2±1.1	58±0.6	554±11.7
Root	**0.3**	23.6±0.3	2.2±0.3	17±0.6	9.5±1.0	3.5±0.3	2.8±0.5	1.8±0.2	31±0.8	14±1.3	53±1.5	697±8.2
	3.9	22±0.6	2±0.1	16±0.6	10.2±0.6	3±0.5	2.4±0.2	1.6±0.1	29.5±1.0	12.5±1.1	56±0.6	665±42.1
	6	19.6±0.5	1.8±0.2	14.5±0.8	10.9±0.6	2.5±0.3	2.1±0.2	1.3±0.1	27.8±1.1	11.3±0.8	59±1.2	640±25.7
	7.9	19±0.6	1.6±0.3	13±1.5	11.5±0.8	2±0.4	1.7±0.4	1.2±0.2	26.4±0.6	10.2±1.2	62±1.2	604±3.4
Inflor.	**0.3**	30.7±0.9	3.3±0.2	18.7±0.3	11±0.6	7.8±0.2	4.8±0.4	1.8±0.1	38.9±0.8	21.5±0.9	45±1.5	573±28.9
	3.9	27.3±0.8	2.9±0.2	18.4±0.4	11.8±0.8	6.9±0.2	4.2±0.8	1.7±0.2	36.7±0.6	20.7±0.7	48±4.2	550±49.1
	6	25.8±0.2	2.7±0.3	18±0.2	12.4±0.9	6±0.4	3.7±0.7	1.6±0.3	35±0.5	19.3±1.2	51±0.6	515±18.5
	7.9	24.7±0.4	2.5±0.2	17.8±0.1	13±0.4	5.3±0.5	3.5±0.5	1.6±0.1	32.8±0.4	18.5±1.0	53±1.0	485±30.4

4.

DISCUSSION

DISCUSSION

Earlier work (Ramoliya *et at*., 2004) indicated that seedling emergence for salt-tolerant legume tree *Acacia Catechu* was reduced to 50% (SG_{50}) in soil with salinity of 6.0 dS m^{-1}, but for the varieties of test plant *Pennisetum glaucum* (L.) Br. SG_{50} was obtained at 4.7, 6.8, 7.9, 6.5 and 5.2 dS m^{-1} for GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743, respectively. This result, would suggest that all varieties of pearl millet were relatively salt tolerant at seed germination. Further, SG_{50} was maximum for GHB 558, GHB 577 and GHB 734 among the five varieties. As a result, these varieties are most tolerant to salt at seed germination stage. However, salt concentration exceeding 7.9 dS m^{-1} was detrimental to seed germination that can be attributed to decreasing osmotic potential of the soil solution. It was observed that seeds became non-viable within a few days in the soil with high concentration of salt. It is considered that germination failure under saline conditions results from either reduction in imbibitions of water by seeds, due to osmotic potential created by NaCl, or toxic effects due to uptake of excessive Na^+ and Cl^- ions by germinating seeds. Many studies indicated that the inhibitory effect of the salinity on germination is mainly due to restriction of water uptake by NaCl (Murrillo-Amador *et. al*., 2002; Khajeh-Hosseini *et al.,* 2003; Okcu *et al.,* 2005; Atak *et al.,* 2006; Kaya *et al.,* 2006). Although the effects of high salt content on metabolic processes are yet to fully elucidated, it has been reported that salinity reduces protein hydration (Marschner, 1995; Slater *et al.,* 2003) and induces changes in the activities of many enzymes (Dubey and Rani, 1990) in germinating seeds. Garg and Gupta (1997) reported that salinity delays as well as decreases germination of most of the crops. In the present study, percent seed germination decreased in response to salinity. Further

percent seed germination at 7.9 dS m^{-1} salinity significantly differed among the varieties. Many investigators (Wahhab *et al.*, 1957; Paliwal and Maliwal, 1972; Garg and Gupta, 1997) have reported a significant varietal difference for seed germination in response to soil salinity. However, germination alone may not constitute a reliable criterion of salt tolerance of a crop. Plant growth response in respect to salinity is of significant importance for screening of salt tolerant varieties and/or species.

Increase in salt concentration reduced shoot height, root length and leaf area of plants for all varieties. Reduction in water content and water potential of leaves, stems and roots of plants grown in saline soils might have resulted internal water deficit to plants, which in term, reduced the elongation of shoots and roots and expansion of leaves. It is found that plants subjected to water stress show a general reduction in size and dry matter production (Taiz and Zeiger, 2006). Moreover root elongation for seedlings grown in control and saline soils at initial 3-week growth stage was remarkably greater than shoot height. Result suggests that *P. glaucum* has a tendency for rapid root extension at early growth stage. It is suggested that rapid root extension ensures existence of plants in dry habitats (Ethrigton, 1987) and is considered an adaptation to survive in dry habitats. Rapid root extension may also hasten establishment of seedlings. Ramoliya *et al*. (2004 a) reported rapid root extension for salt tolerant plant species *Acacia catechu.* Dry weight of leaves, stems and roots of plants decreased as salt concentration increased. This result may be attributed to internal water deficit in plant tissues with increase in soil salinity. Root/shoot dry weight ratios of plants grown in control and saline soils were almost equal and result suggested that salinity reduced root and shoot growth equally.

In general, salinity can reduce plant growth or damage the plants through: (i) osmotic effect (causing water deficit), (ii) toxic effect of ions and (iii) imbalance of the uptake of essential nutrients. These modes of action may operate on the cellular as well as on higher organizational levels and influence all the aspects of plant metabolism (Kramer, 1983; Garg and Gupta, 1997). Result for reduction of shoot growth and leaf area development in varieties of *P. glaucum* with increasing salt concentration are in conformity with the finding of Curtis and Lauchli (1986), who reported that growth in Kenaf (*Hibiscus cannabinus*) under moderate salt stress was affected primarily through a reduction in elongation of stem and leaf area development. Garg and Gupta (1997) reported that salinity causes reduction in leaf area as well as in rate of photosynthesis, which together result in reduced crop growth and yield. Pandya *et al.* (2004) reported decrease in leaf area and dry weight of barley seedlings in response to increase in soil salinity. Ramoliya *et al.* (2004 b) also reported similar result for reduction of leaf area and shoot and root weight for *Salvadora persica*.

Results for dry weight and percent relative dry weight of tissues in response to increasing salinity suggest that there was lowest reduction in dry weight of leaves, while reduction was maximum for stems. Consequently, leaves were most resistant and stems were sensitive to increase in soil salinity. As has been estimated using regression questions given in results, the salt concentrations at which dry weight of salt-stressed plants will be reduced to 50% of control plants (DW_{50}) were 16.8, 22.8, 11.9, 10.9 and 8.2 for leaves, 8.9, 10.9, 9.2, 7.9 and 6.3 for stems and 12.7, 10.8, 9.4, 8.3 and 7.7 for roots of GHB 538, GHB 558, GHB 577 GHB 734 and GHB 743 varieties, respectively. Values of DW_{50} also suggested that leaves were resistant and stems were sensitive to increasing soil salinity. Tissues can be arranged in

decreasing order of salt tolerance as: leaves > roots > stems. Percent relative weight of tissues further suggest that among varieties reduction in dry weight of tissues was lowest for varieties GHB 538, GHB 558 and GHB 577, whereas it was maximum in tissues of varieties GHB 734 and GHB 743. As a result, varieties GHB 538, GHB 558 and GHB 577 are more salt tolerant than varieties GHB 734 and GHB 743.

In principle, salt tolerance can be achieved by salt exclusion or salt inclusion (Marschner, 1995). The salt excluders exhibit water deficit which reduces the plant growth. Adaptation by exclusion requires mechanisms for avoidance of an internal water deficit. Adaptation by salt inclusion requires either high tissue tolerance to Na^+ and Cl^- or avoidance of high tissue concentration. The includers (halophytes) utilize inorganic salts (K^+, Na^+) for turgor maintenance or for the replacement of K^+ in various metabolic functions by Na^+ (Marschner, 1995). Consequently, growth of these plants does not decline under natural conditions and plants are salt tolerant. In the present study, plants of *P. glaucum* survived up to the soil salinity of 7.9 dS m^{-1} and therefore, this crop species is moderate salt tolerant. In addition, salinity caused reduction in growth of plants primarily through lowering the water status (or causing water deficit) in tissues. It is reported that salt excluders suffer from adverse effects on water balance and exhibit much reduced growth rates on saline substrate (Greenway and Munns, 1980). As a result, this crop species can be grouped among salt excluders. Further, salt exclusion is a predominant salt avoidance mechanism in glycophytes (Greenway and Munns, 1980).

In the present study, reduction in relative growth rate (RGR) of plants was induced by salinity stress. It can be attributed to reduction in the net assimilation rate (NAR). Pandya *et al.* (2004) reported a similar result for barley and obtained a significant relationship between NAR and RGR. Cramer and Nowak (1992) found that the

photosynthetic rate of older leaves of barley plants was much more reduced by salinity than that of younger leaves. This result explains why NAR is decreased by salinity. Leaf area of the salt-stressed plants was lower than that of control plants. Further, the old leaves of salt-stressed plants were yellow in colour and those might have lower photosynthesis rate and greater respiration rate than the normal green leaves. Leaf area can limit or promote plant growth by influencing an aspect of NAR, such as photosynthesis or respiration. Lower leaf area, lower photosynthesis and greater respiration rate of salt-stressed plants are the main factors in the reduction of NAR of salt-stressed plants. Cramer *et al.* (1990) also reported that for barley plants grown under salt-stressed conditions, reduced NAR was the main factor to reduce RGR and not the leaf area (LAR). They found that salinity reduces Mn uptake and concentration in barley shoots, which then causes reduced photosynthesis rates, NAR and RGR. The linkage between Mn concentration in the shoot and RGR appeared to be through the effects of Mn nutrition on photosynthesis. First Mn is necessary for photosynthetic reactions to proceed normally: it is part of water splitting enzyme of photosystem – II (Cheniae, 1970). Thus, the decreased Mn concentration in the shoot may limit enzyme activity. Second, they found that decreased RGR is due to decreased NAR and not decreased LAR. Thus, growth is limited by the activity to fix carbon and allocate that carbon to growth, rather than by leafiness of plant. Third, Mn added to saline nutrient solution increased shoot Mn, photosynthesis, NAR and RGR. Thus, alleviating Mn deficiencies in the shoot improved both photosynthesis and growth. In the present study, a significant relationship was found between RGR and NAR for all the varieties of *P. glaucum*. NAR and RGR were greater for varieties GHB 538, GHB 558 and GHB 577 than those for varieties GHB 734 and GHB 743. Consequently,

varieties GHB 538, GHB 558 and GHB 577 are more tolerant to salt than varieties GHB 734 and GHB 743.

In some plant species, salt tolerance associates with accumulation of organic solutes in cytoplasm to balance the osmotic pressure of ions in the vacuoles. The compounds that accumulate most commonly are proline and glycine betaine, although other molecules can accumulate to high concentration in certain species (Hasegawa *et al.,* 2000). Proline accumulates in the cytoplasm without having any detrimental effects on cytosolic enzymes activities (Stewart and Lee, 1974). In the present study, osmotic adjustment was achieved by increase in quantity of proline in tissues when water content decreased with increase in salinity. In addition, the primary role of proline may not be solely as an osmolyte, but it also helps the cells to overcome oxidative stress in salt stressed plants (Rajendrakumar *et al*., 1994). In the present study, there was a positive relationship between proline content in tissues of all the varieties and increase in soil salinity. Further, a negative relationship was obtained between proline content and water potential of tissues. A negative relationship was also obtained between water content and proline content of tissues. Results indicate that increase in salt-induced water deficit was related with increase in proline content of tissues. Among the varieties, proline content was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than that in tissues of GHB 734 and GHB 743 varieties. As a result, GHB 538, GHB 558 and GHB 577 are more salt tolerant than GHB 734 and GHB 743. Similarly, studies conducted on *Cassia montana* (salt tolerant) (Patel and Pandey, 2007) and *Delonix reiga* (moderate salt tolerant) (Patel *et al*., 2008) suggested that salt tolerance was related to the concentration of proline content in tissues.

Concentration of proteins decreased in tissues of plants of all varieties in response to increase in soil salinity. Although it is generally agreed that salt stress causes a significant reduction in protein content of plants (Helal and Mengel, 1979; Pessaralkli *et al.*, 1989; Garg and Garg, 1980; Garg *et al*., 1983, 1990) but it is still not clearly understood whether this decrease is the result of protein degradation or lowered aminoacids incorporation into proteins. Impaired protein synthesis was reported as a result of reduction in plant growth and crop yield under salt and water stress conditions (Ben-zioni *et al*., 1967; Kahane and Poljakoff-Mayber, 1968; Pessarakli *et al.*, 1989). Dubey (1994) suggested that salinity promotes the synthesis of specific proteins, causes either decrease or increase in the level of total and/or soluble proteins, depending upon the plant parts studied, and leads to increased activity and synthesis of many enzymes involved in protein metabolism. In various crop species, a decrease in the protein level in salt-stressed plant parts is attributed to a decrease in protein synthesis, the decreased availability of aminoacids and the denaturation of enzymes involved in aminoacids and protein synthesis (Levitt, 1980). On the contrary increased protein level under salinisation reported in several crops appears to be due to the increased synthesis of pre-existing as well as certain new sets of proteins (Dubey and Rani, 1989). Similar to protein content, carbohydrate content in plant tissues also decreased as the soil salinity increased. Garg and Gupta (1997) reported that increase in salinity and type of salinity influence carbohydrate metabolism of plants. Rathert (1984) studied the effect of NaCl on total root and leaf sucrose and total foliage starch in crops of differing salt tolerance during the early stages of salinity stress. Leaf sucrose level increased most in bush bean (sensitive) but less in rice (moderately tolerant), whereas it decreased slightly in soybean (moderately tolerant) and more in cotton (tolerant). In the present

study, soil salinity also caused reduction in lipid content of plant tissues. Kupier (1984) reported alterations in lipids, particularly in phospholipids and sterols in many plants as a result of salt treatment. Among the varieties, concentration of proteins was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 as compared to that in tissues of varieties GHB 734 and GHB 743. Consequently, GHB 538, GHB 558 and GHB 577 varieties are more salt-tolerant than GHB 734 and GHB 743 varieties.

The cation K is essential for cell expansion, osmoregulation and cellular and whole-plant homeostasis (Schachtman *et al*., 1997). High stomatal K requirement is reported for photosynthesis (Chow *et al*., 1990). The role of K in response to salt stress is also well documented, where Na depresses K uptake (Fox and Gurinot, 1998). In the present study, significant decrease of K content in tissues of all varieties with increasing soil salinity suggests that Na depressed K uptake. Considering selectivity of ions by root cells, it is still unclear which cell types control the selectivity of ions from the soil solution. Further, the exchange of K^+ for Na^+ by the cells in the stele of the roots or in the vascular bundles in stems is considered as one type of control to transport of salt to leaves or growing tissues. Moreover, the significant increase of Na to all the tissues suggests that this mechanism to block Na transfer to growing tissues was not effective in *P. glaucum* at high salt concentration. Decrease in K/Na ratio in all the tissues with increase in salinity suggests that Na was transported in greater proportion than K to the tissues. Many studies have shown that the K^+ concentration in plant tissues is reduced as the Na salinity in the root media is increased (Janzen and Chang, 1987; Lahiri *et al*., 1987; Subbaroo *et al*., 1990). Moreover, K/Na ratio was greater in tissues of GHB 538, GHB 558 and GHB 577 varieties than in tissues of GHB 734 and GHB 743

varieties. As a result, varieties GHB 538, GHB 558 and GHB 577 are more salt tolerant than varieties GHB 734 and GHB 743. Results further suggest that there were no effective mechanisms to control net uptake of Na on root plasma membrane and subsequently its transport to leaf tissues. The pattern of accumulation of K and Na in *P. glaucum* conforms to group C and/or group D plants in Marschner's (1995) classification of the ability of plants to substitute Na with K. In this classification Marschner divided plants into four groups, A, B, C and D depending upon whether K is mostly exchangeable with Na. Sodium has a positive effect on growth in A and B plants (mostly salt tolerant plants). Group C plants contain very little K that can be substituted with Na without a negative effect on growth, and group D plants no K/Na substitution (salt-sensitive plants).

It is reported that uptake mechanisms of both K and Na are similar (Watad *et al*., 1991; Schroeder *et al*., 1994). Plants utilize two systems for K acquisition, low- and high- affinity uptake mechanisms. Na^+ can not move through the plasma member lipid bilayer, but the ion is transported through both low- and high- affinity transport systems, which are necessary for K^+ acquisition. As a consequence, Na^+ could enter the cell through high affinity K^+ carriers or through the low affinity channels called nonselective cation channels that are strongly influenced by Ca^{2+}. These cation channels could allow entry of large amount of Na^+ from a highly saline soil if not adequately regulated (Amtmann and Sanders, 1999). Low affinity K uptake is not inhibited by Na but the high affinity process is restricted (Watad *et al*., 1991; Schroeder *et al*., 1994). Similarly, Na toxicity in plants is correlated with two proposed Na uptake pathways (Maathuis and Sanders 1994; Niu *et al*., 1995). The K and Na profiles of *P. glaucum* suggest that similar mechanism might operate in this species. It is evidenced that Ca^{2+} causes closure of nonselective cation channels and

restricts Na+ uptake (Rus *et al*., 2001). As a result, calcium fertilizers may mitigate Na toxicity to *P. glaucum*.

In general, salinity reduces N accumulation in plants (Feigin, 1985). This is due to the fact that an increase in chloride uptake and accumulation is mostly accompanied by a decrease in shoot nitrate concentration (Torres and Bingham, 1973; Garg and Gupta, 1997). The interaction between salinity and P is very complex and there is no clear cut mechanistic explanation for decreased, increased or unchanged P uptake in response to salinisation in different species (Champagnol, 1979; Grattan and Grieve, 1992). However, it is known that P concentration is related to the rate of photosynthesis, but it decreases the conversion of fixed carbon into starch (Overlach *et al*., 1993) and therefore decrease of P in leaves will reduce shoot growth.

Calcium is important during salt stress, e.g., in preserving membrane integrity (Rengal, 1992), signaling in osmoregulation (Mansfield *et al*., 1990) and influencing K/Na selectivity (Cramer *et al*., 1987). In the present study, there was a significant decrease of Ca content in all the tissues with salinisation of soil. As a result, Na induced Ca deficiency in tissues. It is reported that uptake of Ca^{2+} from the soil solution may decrease because of ion interaction, precipitation and increase in ionic strength that reduce the activity of Ca^{2+} (Janzen and Chang, 1987). Besides the role of Mg in chlorophyll structure and as an enzyme cofactor, another important role of Mg in plants is in the export of photosynthates, which when impaired leads to enhanced degradation of chlorophyll in Mg deficient source leaves, resulting in increased oxygenase activity of RuBP carboxylase (Marschner and Cakmak, 1989). In the present study, there was a negative relationship between concentration of macronutrients (N, P, Ca and Mg) in tissues and increase in soil salinity for all the varieties of *P. glaucum*. Moreover, concentrations of macronutrients in tissues of

varieties GHB 538, GHB 558 and GHB 577 were greater than in tissues of varieties GHB 734 and GHB 743. As a result, varieties GHB 538, GHB 558 and GHB 577 are more salt tolerant than varieties GHB 734 and GHB 743.

It is difficult to suggest mechanistic explanations of salinity influence on micro-element concentration due to relatively smaller differences between control and salinised tissues (Tozlu *et al*., 2000). In the present study, it appears that salinity reduced Zn, Cu and Fe accumulation, but it increased Mn accumulation, at the whole-plant level. Besides, cofactor for enzymes, Fe and Cu are essential for biological redox systems (Marschner, 1995), Mn for photosynthetic reaction as part of water-splitting enzyme of photosystem II (Cheniae, 1970), and Zn for DNA replication, regulation of gene expression and integrity of biomembranes (Marschner, 1995). In addition, high concentration of iron is required for structural and functional integrity of thylakoid membranes and synthesis of ferredoxin and chlorophyll (Marschner, 1995). Pushnik and Miller (1989) reported that iron is involved in photosystem I (PSI) development and assembling the subunits in the thylakoid membranes. The simultaneous decrease of Zn, Cu and Fe in all the tissues of *P. glaucum* might limit the growth of plants. Salinity generates an increase in reactive oxygen species (ROS) which have deleterious effects on cell metabolism (Borsani *et al*., 2001). Superoxide dismutases (SODs) detoxify ROS and may contain Cu, Zn, Mn or Fe as metal components (Slater *et al*., 2003). Increase in Mn content at the whole-plant level might be the requirement of this plant for survival in saline soils.

5.

SUMMARY

SUMMARY

Greenhouse experiments were conducted to assess the differences among varieties GHB 538, GHB 558, GHB 577, GHB 734 and GHB 743 of *Pennisetum glaucum* in response to increasing soil salinity. Sodium chloride (NaCl) was added to the soil and salinity was maintained at 0.3, 3.9, 6.0 and 7.9 dS m^{-1}. For a single variety, twenty polyethylene bags for each level of soil salinity were each filled with 5 kg of soil. For five varieties, five sets of bags were filled with soil varying in salinity. Thereafter, seeds of five varieties were sown in five separate sets of soils contained in polyethylene bags. Ten seeds were sown in each bag on 14 august 2005 for first year experiment and on 11 July 2006 for second year experiment. Seedling emergence was recorded daily over a period of 20 days. For the growth studies, three seedlings that emerged first were left in each of 20 bags at each level of salinity and others were uprooted. Thus, twenty replicates factorialized with four grades of soil (0.3, 3.9, 6.0 and 7.9 dS m^{-1}) were prepared for each variety. For all the varieties, plants contained in 3 bags at each salinity level were harvested at 3, 6, 9 and 12 week growth stages after sowing. Morphological characteristics (shoot height, root length and leaf area), fresh and dry weights of tissues, water content and water potential of tissues, proline content of tissues, protein, carbohydrate and lipid contents of tissues and nutrient content of tissues were determined at all the growth stages. The major findings are summarized as below:

1. Salinity significantly reduced seed germination for all the varieties. There was a negative relationship between seedling emergence and salt concentration. Moreover, salt concentration at which seed germination was reduced to 50% (SG_{50}) was maximum for varieties GHB 558, GHB 577 and

GHB 734. Consequently, these varieties are most tolerant among all the varieties at seed germination stage.

2. There was a reduction in elongation of stems and roots, and expansion of leaves of plants with increasing soil salinity. These results were primarily due to water stress induced by soil salinity.
3. Dry matter accumulation in leaves, stems and root tissues of salt-stressed plants significantly decreased with increase in soil salinity. In general, salinity can reduce plant growth through: (i) osmotic effects, (ii) toxic effects of ions and (iii) imbalance of nutrients. Percent relative weight of tissues suggested that among varieties reduction in dry weight of tissues was lowest for varieties GHB 538, GHB 558 and GHB 577, whereas it was maximum in tissues of varieties GHB 743 and GHB 734. As a result, varieties GHB 538, GHB 558 and GHB 577 are more salt tolerant than varieties GHB 743 and GHB 734.
4. Reduction in relative growth rate (RGR) of plants was recorded with increase in soil salinity. It can be attributed to the reduced net assimilation rate (NAR) and not to leaf area ratio (LAR). The older leaves of salt-stressed plants were yellow in colour and these leaves might have lower photosynthesis rate and greater respiration rate. Leaf area can limit or promote plant growth by influencing an aspect of NAR, such as photosynthesis or respiration.
5. Soil salinity caused significant reduction in water content and water potential of tissues.
6. Proline content in tissues significantly increased in response to increase in soil salinity. Among the leaves, stems and roots proline content was

maximum in leaves and minimum in roots of plants of all the varieties and at all the growth stages.

7. Increase in soil salinity significantly reduced protein, carbohydrate and lipid contents in plant tissues of all the varieties and at all the growth stages.
8. Sodium content in tissues significantly increased, whereas potassium content in tissues significantly decreased with increase of salt concentration in soil. Consequently, the K/Na ratio in tissues also decreased in response to increase in soil salinity.

   Decrease in K/Na ratio in all the tissues with increase in salinity suggested that Na was transported in greater proportion than K to the tissues. Results further, suggested that there were no effective mechanisms to control net uptake of Na and its subsequent transport to leaf tissues. Moreover, K/Na ratio was greater in tissues of varieties GHB 538, GHB 558 and GHB 577 than in tissues of varieties GHB 734 and GHB 743. As a result, varieties GHB 538, GHB 558 and GHB 577 are more salt tolerant than varieties GHB 734 and GHB 743.
9. Nitrogen, phosphorus, calcium and magnesium content in plant tissues significantly decreased as soil salinity increased. Decrease in concentration of macro-nutrients in plant tissues might have reduced growth of the salt stressed plants.
10. Soil salinity caused significant reduction in Zn, Cu and Fe content in plant tissues. The simultaneous decrease of Zn, Cu and Fe in all the tissues of *P. glaucum* might limit the growth of plants

11. Mn content in tissues significantly increased with increase of salt concentration in soil. Increase in Mn content at the whole-plant level might be the requirement of this plant for survival in saline soils.

6.

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